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SEWAGE UTILISATION:

COMPRISING THE FOLLOWING:—

I.

SEWAGE INTERCEPTION SYSTEMS, OR DRY-SEWAGE PROCESSES,

BY GILBERT RICHARD REDGRAVE, Assoc. Inst. C.E.

II.

THE TREATMENT OF SEWAGE BY PRECIPITATION,

BY WILLIAM SHELFORD, M. Inst. C.E.

III.

REPORT OF THE DISCUSSION UPON THE FOREGOING PAPERS.

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SECRETARY.

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Sect. I.—MINUTES OF PROCEEDINGS.

March 28, 1876.

GEORGE ROBERT STEPHENSON, President, in the Chair.

No. 1,474.—"Sewage Interception Systems, or Dry-Sewage Processes." By Gilbert Richard Redgrave, Assoc. Inst. C.E.[1]

"It has long been amongst the most fixed of the certainties which have relation to civilised life, that, wherever human population resides, the population cannot possibly be healthy, cannot possibly escape recurrent pestilential diseases, unless the inhabited area be made subject to such skilled arrangements as shall keep it habitually free from the excrements of the population."[2]

The Author feels that, in basing his observations upon the above quotation from the writings of an able exponent of sanitary science, he cannot too early express the obligations he is under to the medical officers of the Local Government Board for much of the information which he now brings forward. In the Reports of Dr. Buchanan and Mr. J. Netten Radcliffe in 1869, and in the subsequent Report of Mr. Radcliffe in 1874, together with Mr. Simon's Report on "Filth Diseases," dated July 1874, will be found nearly all the facts needed for the thorough investigation of the subject; and it is from the above sources that the following information has mainly been derived.

For the continuous and rapid removal of the excreta from populous districts, there can be no two opinions concerning the advantages to be derived from the use of water as a carrier. A theoretically perfect system of sewage removal would probably be one where a large volume of rapidly-flowing water, passing through the town in impervious open culverts, received from points situated immediately above it, the dejections, liquid and solid, of the entire population, and carried them at once into large rivers, not used for drinking purposes, or direct into the sea.

[1] The discussion upon this Paper was taken in conjunction with the succeeding one, and occupied portions of three evenings.

[2] *Vide* Twelfth Report of the Medical Officer of the Privy Council, p. 17 (1869).

As a modification of this, which would be a most wasteful plan, and which would almost necessitate that privies should be outside dwellings, the modern water-closet has been introduced. This contrivance enables the privy to be removed into the interior of houses, and effects a vast saving in the water supply. Even this plan, however, implies the fouling of a large volume of water. Moreover, it brings with it many evils in the shape of concealed drains and sewer gases; and it is a system eminently unsuited for poor and ignorant populations, owing to its complicated machinery, and its liability to derangement and abuse.

Lastly, there is the water-supplied trough or tumbler-closet, which can be so arranged as to be entirely self-flushing, which needs no movable machinery, and which reduces the amount of water to be fouled to a minimum. Mr. Simon says concerning this plan that, managed or constantly superintended by the local authority, it seems the best of all yet discovered privy contrivances for the uncivilised quarters of towns.[1]

In whatever manner water may be employed for the removal of the excreta, a vast quantity must be rendered impure; and great expense is entailed upon towns where an endeavour is made to defecate and purify such polluted waters before they are finally discharged into rivers or into the sea.

The Author leaves entirely out of consideration all sewage processes involved in the use of water as a carrier, and invites discussion rather upon the contrivances in common use in so-called cesspool and midden towns, where a system of interception or some variety of dry-sewage process is employed.

Many towns are so situated that a water-carriage system for the removal of the excreta is almost an impossibility; and there are large towns where, even when a system of drainage has been carried out at enormous cost, the difficulties of dealing with the polluted waters at the outfall appear so insuperable, that a return to the pre-existing midden system, or to some form of interception, has become almost a matter of necessity.

In connection with the proposed subject it may be as well, in the first instance, to draw attention to the fact that, even where a water-carriage system prevails in any town, some plan of removing house refuse, ashes, and dust, some 'dry system' of collection, must also be in force; while an 'interception system,' however carefully

[1] *Vide* Reports of the Medical Officer of the Privy Council and Local Government Board. New Series, No. II., p. 36.

it may be carried out, still leaves a vast quantity of slop water and surface drainage to be cleansed and defecated at the outfall. Indeed, the Rivers' Pollution Commissioners, in their First Report, after a careful comparison of thirty-one towns, in fifteen of which the midden system prevailed, while sixteen were water-closet towns, came to the conclusion, upon somewhat false premises, that it mattered little, as regards the degree of pollution in the sewer water, whether a system of interception was practised or not. They say: "The retention of the solid excrements in middens is not, therefore, attended with any considerable diminution in the strength of the sewage, although the volume even in manufacturing towns is somewhat reduced." [1]

This state of things must, to a great extent, be brought about by leaky and pervious cesspools, absence of proper urinals, ill-paved roads, and the filthy habits of the population generally, and might be reduced to a minimum by careful scavengering and strict supervision, both of which duties must be uncompromisingly and carefully performed in all towns and areas where cleanliness is sought after and enforced.

The term 'interception' implies the exclusion from the sewers or drains of all fæcal matters, and the possibility of interception involves the existence of a system of sewers, which may, however, have been laid down for the removal only of surface water and slops. Five-sixths of the population of this country are dependent upon some form or other of middens or cesspools for the reception of their excreta; and only in a few large towns, and in these only within the last few years, have efforts been made to remedy the defects and nuisances which appeared to be inseparable from the midden system.

The Author proposes to deal with the subject under four heads:—

I. THE EXISTING PLANS OF SEWAGE INTERCEPTION—

(*a*) By various forms of middens, and by middens of improved construction;

(*b*) By boxes, tubs, and pail-closets;

(*c*) By earth, ash, and charcoal-closets.

II. THE SANITARY ASPECT OF SEWAGE INTERCEPTION.

III. THE COMMERCIAL ASPECT OF SEWAGE INTERCEPTION.

IV. GENERAL CONCLUSIONS RESPECTING DRY-SEWAGE PROCESSES.

It is unnecessary to do more than glance at the old-fashioned pattern of midden-closet, with a fixed receptacle. It can only be spoken of, in the language of Mr. Radcliffe, as "the standard of all

[1] *Vide* Rivers' Pollution Commission (1868). First Report, vol. i. (1870), p. 30.

that is utterly wrong"[1]—constructed as it is of porous materials, and permitting free soakage of filth into the surrounding soil; capable of containing the entire dejections from a house, or from a block of houses, for months and even years; uncovered and open to the rain, the wind, and the sun; difficult of access for cleansing purposes, and wholly unventilated and undrained. Of this foul and disgusting type there are only too many examples in all old towns; and midden-closets of this description prevail almost without exception throughout the manufacturing districts. It will hardly be credited that in the year 1871 there were in Birmingham 13½ acres of space devoted to middens, "practically open to the air."[2]

The first step towards improvement in midden construction is to provide a roof or covering to keep out the wet; and when this is done, precautions should at the same time be taken to insure efficient ventilation through safe channels, that is to say, other than through the privy seat. The old tunnel middens of Liverpool were among the worst types of covered middens. Thus, in the First Report of the Rivers' Pollution Commissioners, mention is made of a single midden 160 feet in length by 6 feet 4 inches in height, and 3 feet in width, entirely devoid of egress for foul gases excepting through the privies.

A further stage of improvement consists in rendering the midden impervious, by constructing it of non-porous materials, and in furnishing a drain to carry off the excess of liquids. The next advance in the right direction shows some simple arrangement for deodorising the contents of the midden with ashes, or some other cheap deodorizer; while the form is modified to permit this to be accomplished readily, and to render it capable of being easily cleansed. As instances of such improvements, Plate 3, Fig. 1, shows the midden privy used at Nottingham, and Fig. 2 the modification of this form of privy adopted at Stamford. In these examples the receptacle is concave, in order that the dejections may gravitate to the centre, and the brickwork is carefully cemented on the inside, to render it impervious. There is also a special opening through which ashes may be thrown on the excreta, and a shaft is carried up for ventilation. The riser of the seat is of brickwork, or in the Stamford example of 2-inch stone; the floors also in both cases are of non-porous materials. The Stamford model is the

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[1] *Vide* Report on Certain Means of Preventing Excrement Nuisances in Towns and Villages. Reports of the Medical Officer of the Privy Council and Local Government Board. New Series, No. II., p. 144.

[2] *Vide* Report of the Public Works Committee on the Sewage Question, 1871, p. xi.

better of the two, for in this instance the seat is hinged, so as to throw up and permit of the ashes being sprinkled on the freshly deposited excreta, and as the pit is shallower, it necessitates more frequent cleansing. The Burnley midden of glazed stoneware, Fig. 3, is provided with an overflow pipe connected with the sewers, and is a good type of a drained, non-porous receptacle. The cost, moreover, is small, only 18*s*., and the danger of leakage is avoided.

Another important advance is gained when the size of the midden is reduced to a mere space under the privy seat: this space should be formed of non-porous materials, and be furnished with a ready means for the removal of its contents. Here entirely changed conditions are arrived at with respect to the removal, which, in middens of this class, must take place at the shortest possible intervals. This alone is an immense improvement upon systems which involve the storing of considerable quantities of putrefying excrement for long periods of time in the midst of crowded populations. The middens in use at Manchester and at Hull are shown in Figs. 4 and 5, and are selected as good specimens of this class. The Manchester midden, now to a great extent superseded by the pail-closet, has a glazed earthenware sloping bottom, with a door conveniently placed for emptying the contents. The emptying takes place fortnightly. This type is known as the "bevel-midden." The Hull closet is similar in arrangement, but the stone floor falls in the opposite direction, and the midden, being less capacious, has to be emptied weekly. The emptying takes place from the front, in lieu of from the side, as at Manchester, the riser of the seat being made movable for the purpose; and as the excrement must be removed through the privy, the plan is defective. The Hull midden, moreover, has no air shaft, which is certainly a drawback: the flue for ventilation in the case of the Manchester privy has, by the bye-laws, to be carried up 3 feet above the eaves of the houses.

From privies of this kind the transition to those with movable receptacles is a natural one, and, in accordance with the shape and size of this receptacle, such privies are called tub, pan, or pail closets. In the simplest arrangements of this type merely a wooden box is placed under the seat for the reception of the excreta; this box when full is tipped into the scavenger's cart, and replaced under the seat. Such was the system in use at Nottingham several years back, and this plan still prevails in some districts in Leeds. At Bilston a fresh box is placed under the privy seat; the full one being carted away to the depôt to be emptied and cleansed. This is a further step in the right direction, and is now almost universally practised when a pail system is employed.

A suggestive midden contrivance is in use at Stockport and in some parts of Leeds. Here, as shown in Fig. 6, a trough is placed under the front part of the seat for the purpose of conveying away the urine to a separate receptacle, or direct to the drains. By this means not only are the midden contents kept much drier, and an entire immunity is secured from splashing, but a smaller quantity of deodorizer for the solids can be employed, and considerable freedom from offensive smell is secured. Urine rapidly undergoes putrefaction, and this process is attended by the production of myriads of living organisms, chiefly vibrios and bacteria, which at once bring about a similar change in all organic matter with which they come in contact. The advantages arising from the separation of the liquid from the solid dejections are therefore most important, from the sanitary as well as from the economical point of view, and when this plan is extended to the pail system, it greatly facilitates the carriage of the tubs, and increases the manurial value of the contents.

The difficulty of cleaning out the angles and corners of the boxes at first made use of, and their non-adaptability to closets of different shapes, led to the employment by preference of oval or round tub-shaped receptacles, which had long been used on the Continent. This was partly due also to the introduction of the invention of M. Goux, patented in this country about six years ago, and this plan was the forerunner of the Rochdale and Manchester pail systems. The company formed to work the Goux patents made use, in the first instance, of oval tubs of the form and dimensions shown in Plate 4, Fig. 7. Before placing these tubs under the closet seat, they were lined with some absorbent refuse material. The lining was adjusted and kept in position by means of the core or mould, which was allowed to remain in the pails until just as they were about to be placed under the seat; the core was then withdrawn, and the pail was left ready for use. This system has been tried at Salford and at Rochdale, and is now in use at Halifax and at Aldershot Camp. The proportion of absorbents in a lining 3 inches thick to the central space in a tub of the above dimensions would be about 2 to 1; but unless the absorbents are dry, this proportion would be insufficient to produce a dry mass in the tubs when used for a week, and experience has shown that after being in use for several days the absorbing power of the lining is already exceeded, and the whole contents have become liquid.

There would appear to be but little gain by the use of the Goux lining as regards freedom from nuisance, and though it removes the risk of splashing and does away with much of the unsightliness of the contents, the absorbent, inasmuch as it adds extra weight, which has to be carried to and from the houses, is rather a disadvantage than otherwise from the manurial point of view. The great superiority of all the pail or pan systems is due to the fact that the interval of collection is reduced to a minimum, the changing or emptying of the receptacles being sometimes, as at Edinburgh, effected daily, and the period never exceeding a week.

After a trial of the Goux process the Rochdale authorities introduced a pail system similar in every respect, but omitting the absorbent lining to the receptacles, and under the able management of Alderman Taylor, Rochdale has become a model town, as respects the mode of dealing with its excreta. The Author proposes to describe the system somewhat in detail, because the plan adopted has served as a pattern to other towns, and because there are indications, in the success that has been attained, that this mode of dealing with human excreta may lead the way to the profitable utilisation of sewage. The tubs employed consist of a paraffin cask cut in half and supplied with handles. A strong cast-iron rim (Fig. 8) is fixed on the inside of the tub about 3 inches down, to form a stop for the lid. The cost of a tub so prepared is 4*s.* 9*d.* Galvanised iron tubs have also been tried; but as their first cost, 9*s.* 6*d.*, is double the price of the wooden ones, and as they only last about half the time, the advantages they possess in point of being lighter and more easily cleansed than the wooden ones, and the fact of their being of considerably greater capacity, do not sufficiently counterbalance these drawbacks. At Birmingham, however, galvanised tubs (Fig. 9) costing 10*s.* each are in general use.

The privies in Rochdale are all numbered consecutively in a district register, and a systematic collection from each of the six districts into which the town is divided for this purpose is carried out. By a well-arranged mode of book-keeping, the carters and collectors are checked in their work, and any omission is at once ascertained. The whole of the work is done in the daytime, and every closet is emptied weekly. The privies are provided with a door giving access to the space under the seat, and when the tub is removed it is at once covered with a lid and placed in a van (Fig. 10), while a clean tub having in it a small supply of disinfecting fluid is substituted for the full one taken away. The cost of the collecting van is £47; it is contrived to hold twenty-four tubs: each van makes five journeys a day. In 1874 five such vans in full work collected weekly from three thousand three hundred and fifty-four privies in all parts of the town.

Another feature of the Rochdale system is the separate collection of the ashes and house refuse. A special tub is set apart for this purpose for every house. It stands under a covered shed, and is provided with a hinged flap for a lid. A cart, the cost of which is £25 (Fig. 11), is employed for the collection of the ashes. This cart accompanies the van in its rounds, so that the removal of the ashes and the excreta is conducted simultaneously. Three such carts, in full work, collected weekly in 1874 from three thousand three hundred and fifty-four ash places throughout the town.

Alderman Taylor has carefully investigated the expense of the collection of the ashes and excreta in a separate form, and from his figures the following table has been drawn up. The figures relate to the collection in 1875.

Weight of excreta collected weekly	96 tons.
" ashes " "	161 "
Total weight	257 "

Number of pails of excreta collected weekly 5,082

$$\frac{96 \times 2240}{5082} = 42 \text{ lbs. average weight per pail.}$$

The expenses of collection, exclusive of wear and tear, interest on capital, and depreciation, are:—

	£.	s.	d.
15 horses at 20*s.* per week	15	0	0
Pay of 30 carters and collectors	33	15	0
Total	48	15	0
Proportionate cost for the collection of the pails containing excreta	27	8	0
" " for collection of ashes	21	7	0
	48	15	0

Cost of collecting 5,082 pails, £27 8*s.* = 1·294*d.* per pail per week, or 5*s.* 7*d.* per pail per annum.

Population using pail system, 50,000.

		d.
Cost per head per annum for excreta therefore	=	6·84
" " " ashes "	=	5·33
Total annual cost per head for collection of ashes and excreta	=	12·17

This estimate agrees closely with the observed cost in other towns, and it may be assumed, with reasonable accuracy, that the annual cost to a population for the removal of its ashes and excreta on the dry system will be about £50 per 1,000, or 1*s.* per head; from this sum the amount realised by the sale of these substances as manures has not been deducted. The Rivers' Pollution Commissioners found that the cost of removing the ashes and excreta, collected on the dry system, from nine important towns in South Lancashire, inhabited by one million one hundred and ten thousand persons using one hundred and thirteen thousand privies, and amounting in the aggregate to 347,000 tons of manure, was little less than 1*s.* per head per annum, and realised rather less than 5*d.* per head of the population. There might be perhaps a slightly increased cost, as indicated by Alderman Taylor's figures, in a separate collection of the ashes and excreta, but the advantages accruing from keeping these substances apart would far outweigh this, when the question of manure-making comes to be dealt with.

Those simple closet arrangements have next to be considered where an attempt is made, injudiciously in many instances, to deodorise the excreta by the application of absorbent material, such as earth or ashes. A closet of this kind may or may not be associated with the pail system. At Manchester, where a form of ash-closet is extensively used (Plate 5, Fig. 12), a cinder-sifter attached to the privy is combined with a pail receptacle. The sifter is so arranged that the fine ash is directed by a shoot on to the excrement, while the cinders fall into a bucket whence they may be taken for re-burning. Various materials have been tried for the sifters, and zinc perforated with $\frac{1}{2}$-inch holes is now used, as it is found least liable to clog. Mr. Radcliffe says, with respect to an inspection of the Manchester ash-closets, that "great differences were in consequence observed in the quantity of exposed excrement, and some differences in the fæcal smell. But where least care had been taken, and also where the pail contained simply the uncovered excrement of several days' accumulation, the fæcal odour was inconsiderable."[1] It would appear from this that there is little to be gained in point of deodorisation by the use of ashes as at present practised. As will be shown later, the true plan of employing ashes or other deodorizers is to apply them in small quantities to the solid matters in a vessel from which the liquids have been excluded.

Probably the best known contrivances for deodorising and disinfecting the excreta deposited in dry closets are those in which advantage is taken of the deodorising properties of dry earth,

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[1] *Vide* Report on Certain Means of Preventing Excrement Nuisances in Towns and Villages. Reports of the Medical Officer of the Privy Council and Local Government Board. New Series, No. II., p. 184.

so prominently associated with the name of the Rev. Henry Moule. In Mr. Moule's closets a supply of earth, contained in a hopper behind the seat, is thrown on to the excreta as deposited, by the action of an ordinary pull-up handle, similar to the pull of a water-closet, or by the weight of the user on a balanced seat or footboard, or by both combined.

Dr. Bond has patented an ingeniously-arranged dry closet, wherein the vessel, fixed beneath to contain the dejections, is so constructed as to receive the liquids and solids into separate compartments. A box for the supply of the deodorising material, consisting of sifted ashes, is attached to the lid (Fig. 13), and the person on entering the closet raises the lid and distributor, and by so doing measures out a charge of the deodorizer; on leaving the seat he closes the lid, and by this means discharges the ashes over the solid excreta.

In Moser's "universal closet" a supply of the deodorant, stored in a chamber at the back of the seat, is spread over the dejections in measured quantities by a pair of bellows actuated by means of a lever handle. In this closet the urine is diverted by a shield or "urine guard" into an independent vessel containing absorbent material.

In Gibson's dry closet a movable shoot attached to a hopper receives a small quantity of the deodorizer, and distributes it on to the excrement by an action similar to that of a shovel. Mr. Gibson has also a stand-pipe with a funnel mouth (Fig. 14), so situated as to receive the urine and convey it direct to the drain, without mingling with the solid excreta. All such contrivances as this aim at economising the quantity of the dry deodorizer, and if the user of the closet can be trusted to avail himself of mechanical means for deodorisation he will, probably, be just as likely to avail himself of a supply of dry material, situated conveniently for the purpose, to be thrown on the dejections with a hand scoop. All mechanical devices for the distribution of deodorizers which the Author has yet seen, even including the simple ash-sifter at Manchester, are more or less liable to get out of order, and are ill-adapted, therefore, to "uncivilised populations." With reference to the separation of the liquids and the solids and the use of earth or ashes, it has been conclusively shown that, to absorb the urine and deal with the excrement of an average population, a daily supply of earth amounting to 4½ lbs. per head will be required: and when this quantity comes to be used for a large population the cartage to and from the depôts will be enormous. When the urine is separately stored, there still remains the difficulty of dealing with it, unless, as Mr. Gibson proposes, it is allowed to run direct into the sewers.

In ash and charcoal closets similar arrangements to those already examined in the case of dry-earth closets as a rule prevail.

Animal charcoal forms such an excellent deodorizer, that when the urine is kept apart from the fæces, from ½ oz. to ¾ oz. suffices, if carefully distributed after each use of the closet, to remove all disagreeable smell from the solids. This is an important consideration when the cost of collection and carriage has to be dealt with, and indicates the right way of using deodorizers. The Carbon Fertiliser Company has devised a first-rate separator-pail, for keeping the liquids apart from the solids (Fig. 15). The object is effected by a horizontal perforated diaphragm, which retains the fæces, but allows the urine to pass through into the lower part of the receptacle. This plan of separation is the only one that answers, where the chamber slops are also thrown into the pails.

The sanitary bearings of dry collections have next to be considered; and upon this point medical testimony, while it is unanimous in condemning the dangerous and disease-spreading character of the old unimproved midden of the accumulative type, tends conclusively to prove that, under a well-managed tub or pail system, nearly all the former objections to a dry process are removed. Messrs. Radcliffe and Buchanan say in their Report, dated 1869, dealing with this subject: "It is impossible not to be struck with the advantage that a tub or pail system has in relation to diseased excrement. The facility and thoroughness with which any required chemical disinfection may be done, and the way in which the excrement itself can be wholly got rid of, leaving none of its products behind—nothing soaking into the ground, or hanging about middenpits or sewers—obviously suggest most important powers possessed by this system for preventing spread of the excremental diseases."[1] This, it must be remembered, is an advantage common to no other method of dealing with excreta, and is one rendered peculiarly valuable by the increased knowledge respecting the propagation of diseases of the typhoid class.

All authorities are unanimous also in declaring that the pail system, when properly carried out, as at Rochdale, reduces the excrement nuisance to a minimum, and both in those towns that have come under the Author's personal observation, and from the evidence gathered from the inhabitants themselves, little inconvenience is caused either to sight or smell by the use of the tubs

[1] *Vide* Twelfth Report of the Medical Officer of the Privy Council, p. 138 (1869).

or pails, or by the mode adopted for changing or collecting them. From the sanitary point of view Mr. Simon's testimony is of the highest value, and this gentleman pronounces respecting dry processes as follows: "That, failing a water-system, both large and small populations can obtain under other and amended systems of privy-management a complete or comparatively complete freedom from excremental nuisance and injury."[1]

But it is from the commercial aspect that the dry system of dealing with human excrement presents its most important advantages, and if ever the manufacture of manures from excreta is to become a source of profit—and it is impossible to doubt that it ere long will do so—it will be effected by a proper treatment of pail-carried excreta. In spite of all that Stock Exchange sewage companies may urge to the contrary, experience has repeatedly demonstrated, that when once the valuable manurial components of the excrements have been diluted with 100 times their weight of water, the only method of utilising the liquid as a manure is to apply it in definite quantities to properly-prepared land; though even when this is effected under the most favourable circumstances, there are no evidences that a profit can thus be obtained from sewage. When, however, the liquid and solid dejections, collected free from admixture with foreign substances, and in an undiluted form, have to be dealt with, the question of their profitable utilisation is placed upon a different footing. When, moreover, by the employment of closets of some such construction as that shown in Fig. 16, the collection of the liquids and solids can be carried out in separate vessels, the possibility of making a profit by the manufacture from the excreta of solid manures may be predicted with certainty.

From careful observations of the quantities of excreta collected in pails, it may be assumed that each individual of an average population will yield 1 lb. of mixed pail sewage per diem, or 3¼ cwt. per annum. The cost of carrying this quantity to a depôt is, in accordance with the Rochdale estimate, 6·84*d.* per head, or say 3*s.* 6*d.* per ton. Allowing for interest on capital and depreciation on works and plant, it will not be far wrong to assume the cost of the pail stuff, delivered at the wharf or depôt, at 4*s.* per ton. By processes familiar to chemists, this ton of pail sewage, the produce of 6·16 average individuals, is found to possess in the form of a finished manure a value, in round numbers, of 16*s.*

[1] *Vide* Reports of the Medical Officer of the Privy Council and Local Government Board. New Series, No. II., p. 34.

That is, the theoretical annual value of the fæces, and that portion of the urine voided with the fæces, of an average population amounts to a little over 2*s*. 6*d*. per head, while the average value of the whole of the excreta has been variously estimated at from 8*s*. to 10*s*. per head per annum.

General Scott, C.B., Assoc. Inst. C.E., who has devoted great attention to the production of manures from dry sewage, has recently demonstrated that from the liquid and solid dejections collected on the pail system it is possible to prepare, at a reasonable profit, concentrated manures containing from 5 to 6 per cent. of ammonia and from 8 to 10 per cent. of phosphoric acid, and which would therefore command a market value of from £7 to £8 per ton, and upwards. Manures of this class are sold at prices approximating to their theoretical value, *i.e.*, their value as indicated by chemical analysis; while feeble manures, such as those prepared from sewage sludge and the contents of ordinary ash-pits and middens, rarely fetch more than from one-fourth to one-tenth of their theoretical value. It would take about 10 tons of pail sewage to produce 1 ton of the above-described concentrated manure, or each ton of such manure would be the annual produce of sixty-two average individuals. As will readily be understood, when the excreta are largely mixed with earth, charcoal, or ashes, which give weight and bulk without value, the possibility of producing high-class manures becomes out of the question. Here is at once the reason why all the poor manures, made from mixtures of excrement with what have been termed "profligate associates," are sold with difficulty, and rarely fetch more than a few shillings per ton. Efforts to obtain more concentrated mixtures have from time to time been attended with fair success. The Author has lately inspected the Paris Municipal Works at Bondy, where sulphate of ammonia is being made from the liquid contents of the *fosses mobiles* at a small profit. Urine collected separately was some few years back profitably treated at Glasgow for the extraction of carbonate of ammonia; and only last year a company at West Bromwich succeeded in producing a concentrated manure, by boiling down the mixed pail contents to dryness, which commanded £7 10*s*. per ton. The works had, however, to be abandoned on the score of creating a nuisance.

The conclusions formed by the Author upon dry-sewage processes are:—

1. That in towns where, for local reasons, a water-carriage system for the removal of the excreta is impracticable, it is

possible, by a modification of the midden-closet, to effect this removal without nuisance and without injury to health.

2. That the removal of the excrements can best be effected by employing pail- or tub-closets which provide for the separation of the liquid and the solid dejections, and are emptied at intervals not exceeding one week.

3. That the local authority should conduct the removal of the excreta and also of the ashes, and should regulate this removal by stringent supervision.

4. That it is possible, by suitable manipulation, to prepare from human excreta, collected on the dry system, concentrated manures which will repay the cost of collection and cover all the expenses of their production.

The Paper is accompanied by a series of diagrams, from which Plates 3, 4, and 5 have been compiled.

No. 1,475.—"The Treatment of Sewage by Precipitation." By WILLIAM SHELFORD, M. Inst. C.E.[1]

PROBABLY no question of practical interest at the present day is more in need of a record of facts, to serve as a basis of future improvement, than the treatment of sewage. In the hope of contributing some useful information relating to the method of treatment known as the 'precipitation' or 'tank system,' the following notes have been selected from those made during several years' professional acquaintance with the subject.

In 1869, 'precipitation' received new life by the publication of a pamphlet, entitled "The Sewage Question Settled," by the Native Guano Company. That pamphlet described the A B C[2] process as then carried on at Leamington, where the company were treating the sewage of twenty thousand persons (600,000 gallons daily), and it stated that, by the use of ½ ton of chemicals, they obtained 5 tons of dry manure per day, at a cost of 30*s.* per ton, including all expenses, even interest on capital. The company showed by analysis that the manure contained 4·2 per cent. of ammonia, and succeeded in obtaining £3 10*s.* per ton for it. The net profit of £2 per ton thus shown, or £10 per day, naturally attracted attention, and the interest was increased by the story told to all comers that the patentee had got the idea of using blood from St. Paul's Epistle to the Hebrews, 9th chapter, 22nd verse, where it is written, "Almost all things are by the law purged with blood." Leamington was a favourable place for the experiment; but time soon showed that the practical difficulties had not been met. Meanwhile the Native Guano Company obtained a concession of sewage from the Metropolitan Board of Works, with leave to erect works at the outfall of the Southern Metropolitan Sewers at Crossness, for the treatment of 500,000 gallons daily, and proceeded to demonstrate their process there. During the erection of the works the £5 shares of the company rose to £40, and the excitement produced by that circumstance, and the constant criticism of the process, led to the Crossness experiment being regarded by common consent, the company scarcely excepted, as a crucial test; the more so because the company put the whole matter under the independent superintendence of the Engineer and Chemist of the Metropolitan Board, whose reports were published in January 1873. These were utterly con-

[1] The discussion upon this Paper was taken in conjunction with the preceding one, and occupied portions of three evenings.

[2] So named from the initials of the principal ingredients—alum, blood, and clay.

demnatory of the pretensions which the company had put forward in their pamphlet, inasmuch as the Engineer, Sir J. W. Bazalgette, C.B., M. Inst. C.E., showed that the cost of 142 tons of manure manufactured at Crossness was £6 6s. 4d. per ton, "exclusive of rent, interest on capital, depreciation of plant, and other incidental items;" and the Chemist, Mr. Keates, reported that "the value of the manure, as judged by its chemical composition, does not exceed 20s. per ton."[1] After every allowance had been made for the poverty of the sewage treated, its small quantity (viz., 14,600 gallons per hour, instead of 20,800 gallons, for which the works were constructed), the cost of lifting the sewage by pumping, the imperfect system of drying, the exceptional cost of chemicals, and other items for which the company might reasonably claim some consideration, it was generally felt that not only was the "sewage question (not) settled," but the more homely problem of making two ends meet could not be solved by the A B C process at Crossness.

That time marks a new era in the history of 'precipitation.' Towns which asked and obtained £500, and even £1,000, per annum for the concession of their sewage have since abandoned their claims; and in a few cases sanitary authorities have agreed to pay small sums for the removal of the nuisance.

Such a collapse has laid the Company open to attacks which were often undeserved, and to blame which was certainly unmerited. There can be no doubt that the company sacrificed itself by submitting to a public test before mastering the facts or acquiring the experience necessary for the application of the process on a working scale. This failure, however, not only affected the company, but was considered a death-blow to precipitation generally, which was so far good that it led to the present opinion of the public with regard to the value of sewage—an opinion which seems to be everywhere finding expression, viz., that whatever the value of sewage may eventually prove to be, no means yet exist by which a profit can be realised from it. Irrigation by sewage has its troubles; filtration of sewage is not wanting in difficulties: yet each system has its advocates. Precipitation is represented by several companies, which are still before the public and have not given up the attempt. Biding their time, they are evidence, if evidence be needed, of the wide field open to a good precipitation process.

It is not proposed in this Paper to advocate, much less to condemn, any process, nor to give a description of all the precipitation processes; but it is desired to bring out the practical points to

[1] *Vide* the "Financier," 22nd January, 1873.

which attention should be given, and to indicate the direction which improvements should take.

It will be convenient to do this under the following heads:—

I. Analysis of Cost of Native Guano, and the Lesson to be learned from it.

II. Description of Model Works erected at Battersea for Experiments on Sewage with Mr. Dugald Campbell's Process, and the Results obtained.

III. Description of some of the Works erected for the Utilisation of the Sewage of Tottenham, by Whitthread's Process, and the Result.

IV. Conclusions.

I. Analysis of Cost of Native Guano, and the Lesson to be learned from it.

The Native Guano Company at first stated that at Leamington the cost of manufacturing the manure did not exceed 30*s.* per ton. Sir J. W. Bazalgette reported that the cost of manufacture at Crossness was £6 6*s.* 4*d.* per ton, including pumping the sewage.

The total quantity of manure manufactured at Crossness was about 142 tons, at a cost of £895, divided thus:—

							Cost per ton of manure.					
	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*
Chemicals	293	16	10				2	1	4			
Manufacturing wages	220	12	2½				1	11	1			
Chemical supervision	33	10	4				0	4	9			
Manufacturing stores	47	13	0				0	6	8			
Total cost of manufacturing, exclusive of engine-power and coals for drying				595	12	4½				4	3	10
Coals	230	11	3½				1	12	5			
Mechanical supervision	38	0	10				0	5	5			
Engine stores . .	14	7	4½				0	2	0			
Total cost of engine-power, including pumping sewage and coals for drying				282	19	6				1	19	10
Sale account — Bagging and loading .	8	15	3				0	1	6			
Office—Wages of boy	7	16	1½				0	1	2			
				16	11	4½				0	2	8
				£895	3	3				£6	6	4

The quantity of chemicals used was $166\frac{3}{4}$ tons, the cost of which was, as above, £293 16*s.* 10*d.*, or £1 15*s.* 3*d.* per ton. But the chemicals, in the condition in which they were purchased and used, contained about 50 per cent. of moisture, which reduced their weight in the dried manure to 81 tons, and made their cost in the dry state $\frac{£293\ 16s.\ 10d.}{81}$ =	£3 12 6	per ton.
To which must be added the extra labour required for the manipulation of the $166\frac{3}{4}$ tons instead of 81 tons, and the cost of drying the $166\frac{3}{4}$ tons down to 81 tons—say	0 15 0	per ton.
Total cost per ton of the dry chemicals .	£4 7 6	
Deduct this from the total cost of the manure	6 6 4	
And there remains a balance of . . .	£1 18 10	per ton
for every expense but the chemicals and the pumping of the sewage. Again, deduct cost of pumping the sewage—say	0 10 0	per ton of manure.
Total expenses, exclusive of pumping and chemicals	1 8 10	,,

Therefore the expense of the process may be taken to be only £1 8*s.* 10*d.* per ton of manure, if the cost of the chemicals is excluded. But inasmuch as the cost of the manure was £5 16*s.* 4*d.*, without pumping the sewage, instead of £1 8*s.* 10*d.*, it is impossible to escape the conclusion, that it was the cost of the chemicals which mainly brought about the failure of the experiment at Crossness.

Turning now to Leamington, the Company stated that $\frac{1}{2}$ ton of chemicals had been used and 5 tons of manure obtained daily at a cost of 30*s.* per ton.

The cost of ½ ton of chemicals would, at £4 7*s.* 6*d.* per ton, as above, be £2 3*s.* 9*d.*, or $\frac{£2\ 3s.\ 9d.}{5}$ = per ton of manure	£0	8	9
Add the other expenses, as at Crossness, but without the cost of pumping the sewage, since it flowed by gravitation through the works	1	8	10
Total cost of manure at Leamington . .	£1	17	7

Or 38*s.* per ton, as against 30*s.* per ton stated by the Company. It thus appears that the cost of the chemicals at Leamington was comparatively unimportant, and that the Native Guano Company actually had the settlement of the sewage question at Leamington in its hands if it sold the manure at £3 10*s.* per ton.

Although the details of this estimate may be open to exception, the fact remains that it was the chemicals which made the difference between the cost of the manure at Crossness and at Leamington; and it will be worth while now to see how this great difference is to be accounted for.

The ½ ton of chemicals at Leamington was applied, according to the company's statement, to 600,000 gallons of sewage, which is equivalent to a dose of 1·86 lb. per 1,000 gallons. Many changes appear to have been made, and the dose seems to have been afterwards increased at Leamington, Leeds, and other places until, at Crossness, it reached 31·8 lbs. of moist chemicals per 1,000 gallons. The increase in the quantity of the dose was accompanied also by a great alteration in its constituents and their proportions. They were as follows:—

Chemicals used in A B C Mixture.	Leamington. Parts by weight.		Crossness. Parts by weight.	Dose per 1,000 gallons. Leamington. lb.	Dose per 1,000 gallons. Crossness. lbs.
Alum	95·62	26·77	nil	1·78	13·78
Clay		68·85	43·33		
Blood		1·78	a little	·03	..
Animal charcoal .	2·54	1·91	48·33	·05	15·37
Vegetable charcoal.		·63			
Magnesia . . .	..	·06	nil	·001	..
Salt	..	occasionally	nil	..	..
Permanganate of potash	..	occasionally	nil	..	..
Sulphate of alumina	..	nil	8·33	..	2·65
Lime	..	nil	a little	..	..
		100·00	100 00	1·861	31·80

Thus the principal difference was a large addition at Crossness to the proportion of charcoal used; and this fact will have more significance when the actual quantity is noted, amounting at

Leamington to 0·05 lb., while at Crossness it was 15·37 lbs., per 1,000 gallons. The effluent water at Crossness was reported by Mr. Keates to be "extremely good"; and it was certainly much better than that obtained at Leamington by the above mixture. Possibly the superiority of the effluent water at Crossness was due to the charcoal. If so, the company would appear to have thought that charcoal could be added in large quantities for the purpose of deodorising both the effluent water and the sludge, as long as the selling price of the manure was arbitrarily fixed at £3 10*s.* per ton without reference to its composition.

The Native Guano Company has doubtless long since learned the lesson, that while a dose of 1·86 lb. of A B C mixture per 1,000 gallons of sewage may leave a profit on manure sold at £3 10*s.* per ton, yet when the dose is increased to 31·8 lbs. per 1,000 gallons it can only result in a heavy loss; or, in other words, that a moderately good effluent may be produced, and a profit may be shown on the manufacture, if the manure will sell for £3 10*s.* per ton, but that it will not pay to produce an "extremely good" effluent by the admixture of a large quantity of precipitants of low manurial value.

II. Description of Model Works erected at Battersea for Experiments on Sewage with Mr. Dugald Campbell's Process, and the Results obtained.

The process known as "Campbell's Patent" was introduced in 1872. It consists in adding phosphate of lime in a soluble state to the sewage as it enters the works, and in precipitating it after sufficient admixture by a further addition of lime. It was worked for six consecutive days in July 1872 at Tottenham, and the results are stated to have been that $3\frac{1}{2}$ million gallons of sewage were treated with superphosphate of lime (made of $6\frac{1}{2}$ tons of bone-ash and $4\frac{3}{4}$ tons of brown acid) and 4 tons of lime, total $15\frac{1}{4}$ tons of chemicals. The yield was 22 tons of dried manure, and the effluent water was reported by chemists as "very satisfactory."

The dose of chemicals was 9·76 lbs. per 1,000 gallons, the cost being £57 2*s.* 6*d.*,[1] or £3 14*s.* 9*d.* per ton, and

	£	s.	d.
$\frac{£57\ 2s.\ 6d.}{22}$ = ...	£2	11	11
Add other expenses as at Crossness, excluding pumping the sewage, which is not part of the process .	1	8	10
Total cost of manure per ton	£4	0	9

[1] The cost of the chemicals is given as £66 in the Appendix, the difference being due to a higher estimate of their market value, but the margin of £1 per ton, hereafter mentioned, would more than suffice to cover it. W. S.

The value of the manure was estimated by several eminent chemists at about £5 per ton.

The following is one of the analyses:—

Moisture	19·04
Organic matter containing nitrogen 1·2, equal to ammonia 1·45	15·26
Precipitated phosphate of lime	23 14
Insoluble phosphates	3·80
Sulphate and carbonate of lime, and lime uncombined	19·25
Alkaline salts and magnesia	3·14
Insoluble matter	16·37
	100·00

The manufacture of this manure would thus show a margin for carriage, &c., of about £1 per ton, if the moisture in the chemicals did not exceed that in the manure analysed, viz., 19 per cent.

The works at Tottenham were not then applicable to a continuous treatment of all the sewage by this process, nor were the owners of the patent in a position to execute the necessary additions to them. Moreover, further experience was wanting on several points before applying the process on a large scale, and it was consequently determined to erect small works for experimental purposes.

Permission was obtained from the Metropolitan Board of Works to pump sewage from the Heathwall Sewer, in Battersea Fields, skirting the foot of the rising ground of Clapham Common, and receiving the drainage of a population estimated at about ten thousand. The sewer is egg-shaped, 5 feet by 3 feet 4 inches, and the fall is 1 in 1,800 (Plate 6). It receives surface drainage as well as the house sewage. The minimum depth of sewage is 6 inches, at night, equal to 345,000 gallons per twenty-four hours. The maximum depth in dry weather is 10 inches, equal to 900,000 gallons per twenty-four hours. When filled the sewer delivers 15 million gallons per twenty-four hours.

Observations were taken on the depth three times almost daily, beginning on the 11th of September, 1873, and continuing to the 20th of June, 1874, and again from the 26th of January to the 22nd of May, 1875. The two series of observations gave the same general results (Plate 6). These show, first, that in this sewer there was very little interference by storm water with the ordinary flow; secondly, that the volume of storm water when it occurred was such as to make the treatment of the sewage most difficult on account of the quantity, but at the same time the treatment was unnecessary, because of the extreme dilution of the sewage;

thirdly, that sewage may be treated by precipitation where the gradients of the sewers in the district and other circumstances are suitable, even though it be conveyed by the 'combined' instead of the 'separate' system of sewers.

The rainfall during the observations was, according to Mr. Symons:—

1873.	Inches.		1874. Inches.	1875. Inches.
September	2·46	January	1·18	3·22
October	2·97	February	0·91	1·06
November	1·87	March	0·39	0·69
December	0·48	April	1·26	1·53
		May	1·14	1·61
		June	2·05	—

Both 1873 and 1874 were dry years, the total rainfall in London being 22·67 inches and 18·82 inches, as against the average of 25·68 inches.

The sewage was generally fresh, but it sometimes suddenly became foul. On some occasions it was loaded with suspended matter, chiefly sand, and on others it was almost clear water. But it was at all times what might be called a weak sewage.

One of the arches in the viaduct of the London, Chatham, and Dover railway was hired, and works were erected for the treatment of a maximum quantity of 5,000 gallons per twenty-four hours. They consisted of—

1. An ordinary hand pump for raising the sewage.
2. Two mixers worked by a continuous shaft from the hand pump, so arranged as to prevent the subsidence of the chemicals in the water with which they were mixed, and at the same time to bale the due proportion of each into the sewage.
3. A mixing trough ('salmon ladder') for effecting the admixture of the chemicals with the sewage (Plate 6).
4. A series of six concrete tanks for the precipitation (Plate 6).
5. A series of filter beds for partly drying the sludge.
6. A Milburn's drying machine for completing the dried manure.

The two mixers were an adaptation of the water-wheels employed in Alpine rivers for raising water by buckets attached to their rims. Each of them consisted of a wheel which revolved in a suitable vessel containing the chemicals, diluted with water, at a sufficient velocity to prevent their subsidence, and at the same time by means of cups attached to the ends of the spokes the right quantity of each chemical was raised and thrown into the 'salmon ladder' containing the sewage. These mixers have always worked well, and have given no trouble.

The mixing trough, made like a 'salmon ladder,' was first applied by the Author to these works, and was found to be so convenient and economical, that he afterwards used it on a large scale at Tottenham (Plate 6).

The tanks were arranged similarly to those for the works at Crossness. They were capable of use for the treatment of the sewage either during its continuous flow through them, or by intermittent flow into each, and then allowing the sewage to remain at rest during precipitation, but without stopping its flow into the works. Each tank was a cube of 4 feet, and held about 415 gallons. The series of six held 2,500 gallons, or twelve hours' flow of sewage. When worked by 'continuous flow' the two first tanks are used alternately and receive most of the precipitate. From these the flow of the sewage is directed through the remaining four, but any one of them can be emptied and cleaned by shutting it off with sluice boards. When worked by 'intermittent flow' the tanks are filled, and after a proper lapse of time for the deposit are cleaned in succession. One advantage of this arrangement of tanks is economy in first cost. It is evident that if one tank were used for twelve hours' flow a duplicate must be provided during cleansing.

On the other hand, the series of six could be kept equally clean by providing only one-sixth more tank-room. It has further the advantage of .concentrating the precipitate in a small space, by which means it can be more cheaply removed, and the necessity for removing it promptly is greater than if it was spread over the surface of a large tank. The works are thus frequently cleansed —an important point, too little attended to in precipitation processes. The sludge or precipitate is discharged from the bottom of the tanks into a channel communicating with the filter beds.

The filter beds for partly drying the sludge were of the commonest description. They have worked satisfactorily, and have been used by the Author on a large scale at Tottenham with equally good results.

Milburn and Company's machines for drying sludge were also adopted at Tottenham, where they gave results which will be interesting. Suffice it to say now, that the small machine made for these works was quite satisfactory in its operation, and, after allowing for certain disadvantages inseparable from its diminutive size, equally so in its results.

These works have been in operation, under the name of the "Model Works of Campbell's Patent Manure and Sewage Company, Limited," since September 1873. Thirty-one experiments were made from that date to the 12th of May, 1875, during which period 155,000 gallons of sewage were treated. They have since been intermittently in operation as occasion required.

Numerous experiments were made to determine the best proportion of chemicals to be used, and eventually that found to produce a good effluent water of greater purity than would pass what is known as the "Thames Conservancy Standard" was a dose of 10 lbs. of superphosphate and 3 lbs. of lime, or a total of 13 lbs. of chemicals per 1,000 gallons. The effluent water as it left the works was either neutral or gave a slight alkaline reaction, and was more suitable for irrigation purposes than raw sewage.

The precipitate, or sludge, when run upon the filters, contained 90 per cent. of water and was about 1 foot deep. The heavier matter at once subsided and left the water on the top; but in consequence of the absence of clay, and the porous condition of the sludge, the water percolated through both it and the filter, until a comparatively solid stratum of sludge, of the consistency of mortar, was left. The filters were found to work best when the partially-dried sludge did not exceed 3 inches in thickness. The sludge when shovelled off the filters contained 80 per cent. of moisture, and was accumulated for two or three weeks in that state without being at all offensive, until a sufficient quantity had been prepared for Milburn's machine, which was necessarily worked intermittently. The sludge from Campbell's process appears remarkably adapted for drying by filtration, a circumstance due to the absence of clay in the precipitants employed, to the large proportion of chemicals compared with the sludge, and to their porous condition. Its importance can hardly be overrated, inasmuch as it solves the difficulty of drying, which has been more troublesome than any other mechanical question. Experiments and analyses showed, moreover, that the value of the sludge was not affected by its filtration, whilst the quantity of moisture abstracted by it was at least one-half, even after tho sludge had been brought to much greater consistency by draining off the water as it collected upon the surface.

The experiments were made on sewage collected in dry weather only. The results obtained did not always equal the one above referred to at Tottenham, for although the quantity of sewage in dry weather at the Model Works flowed with tolerable uniformity, the quality varied considerably and at short intervals, so that there was also great variety in the results. This variation in quality was an advantage in experimenting, and would have been valuable if the sewage had at any time been rich.

The value of the manure was much affected by the presence of sand, which always formed 28 to 36 per cent. of the total weight, as against 20 per cent. or less at Tottenham. Such a proportion of sand may have been present in the whole of the sewage, and may have been consequent upon its passing through drains laid with steep gradients through the gravel of Clapham Common; but it was no doubt partly due to the difficulty of getting a fair sample of sewage from a sewer in which the suction pipe was necessarily placed close to the bottom, where it drew more than a due proportion of the heavier matters in suspension. The effect of the sand, as it increases the bulk, does not diminish the gross value of the manure obtained, but it reduces the value per ton and renders it less saleable.

In comparing the experiments, the cost of the superphosphate has been taken at £5 per ton, and the lime at 15*s.* per ton, those being the prices at which they could then be purchased, and higher than the prices in the Tottenham experiment. The manure was valued on the analyses of the chemists who reported upon it, taking ammonia as worth 18*s.* per unit, precipitated phosphates at 3*s.* 3*d.* per unit, and allowing nothing for the insoluble phosphates or organic matter.

On these bases, the best result at Wandsworth Road showed

	£	s.	d.
that the cost of chemicals per ton of manure was .	£2	13	4
Add other expenses as before, from Crossness . .	1	8	10
Total cost per ton	£4	2	2

And the value of the manure corrected to contain 18 per cent. of sand and 10 per cent. of moisture was £4 7*s.* 2*d.* per ton, thus showing a margin of 5*s.* per ton after payment of expenses. The worst result showed that the manure was worth about £3 per ton, or sufficient to pay the cost of the chemicals and leave a margin. Therefore it would appear that Campbell's process may be used for treating sewage equal to that of Tottenham, so as to repay the expenses of manufacture at least, and for sewage equal to the weakest at Wandsworth Road so as to repay the cost of the chemicals, and leave the expense of labour and drying (found at Crossness to be, as before stated, £1 8*s.* 10*d.* per ton) to be borne by the public. In either case the resultant manure, which contains from 13 to 21 per cent. of precipitated phosphate of lime from bone ash, in addition to the organic matter and ammonia usually obtained by precipitation processes, would probably compete better with other manures in the market than those sewage manures which consist in great part of precipitants having no manurial value.

In confirmation of the above results particulars are given in the Appendix of experiments, both at Tottenham and at Wandsworth Road, in which the cost of chemicals and the value of the manure are reduced to the same standard for comparison. There are also added some analyses of the effluent water produced by Campbell's process at Wandsworth Road, and some information upon the comparative value of artificial manures.

III. Description of some of the Works erected for the Utilisation of the Sewage of Tottenham, by Whitthread's Process, and the Result.

Whitthread's process was brought out in 1872. It is described, in the Report of the Sewage Committee of the British Association of that year, as consisting in the addition of a mixture of dicalcic and monocalcic phosphate (the latter being added as commercial superphosphate), and then afterwards a little milk of lime. Mr. Hope, V.C., at the Social Science Congress, in the same year (1872), said of it:

"As yet the process has only been tried experimentally; it has not been thoroughly investigated, nor, in all probability, perfected, yet the result so far is remarkable and encouraging, because, although of course it cannot extract the ammonia in solution, it does remove altogether the other forms of organic nitrogen in solution. It therefore, to some extent, purifies the sewage; while not only is there a greater value in the matters removed by it from the sewage, than in those removed by any other process, but the material added is in itself a valuable manure."

Mr. Hope's opinion was formed on an experiment made on his Romford farm. The process was afterwards tried on a working scale at Luton and at Enfield, early in 1874; and in the latter part of the same year the proprietors formed a small private company for the purpose of working an agreement with the Local Board of Tottenham for the treatment of the sewage of that district.

The works then existing were transferred to the company, and the requisite additions were made to them. These were not of much interest for the purpose of this Paper, except in reference to the means adopted for mixing the chemicals with the sewage by a 'salmon ladder' mixer, and for drying the sludge. The sewage was pumped up into the precipitating tanks at the rate of about $1\frac{1}{4}$ million gallons per day, and a 'salmon ladder' mixer after the pattern of that used at Wandsworth Road was placed between the pump and the tanks, through which the sewage flowed by gravitation at a velocity sufficient to prevent the subsidence of the chemicals, and with a disturbance enough to incorporate them thoroughly. This 'salmon ladder' (Plate 6) was 77 feet long by 6 feet wide and 2 feet 6 inches deep, and was fitted with groynes, 3 feet apart, projecting from each side alternately. It was raised 2 feet 9 inches at the inlet of the sewage, and had an inclination of 1 in 28. The phosphate was added to the sewage at the top of the ladder, and the lime at any suitable point in its length. Although the ladder increased the lift of sewage by nearly 2 feet, no objection was made to it. It was worked regularly from the time it was completed, and gave general satisfaction as a simple and effective means of insuring the admixture of the chemicals without machinery and its attendant cost and risk of failure.

To dry the sludge it was at first determined to use Needham and Kite's presses, and to reduce it to a solid state containing 50 per cent. of moisture; contrary to the advice of the Author, the presses and pumps to supply them were erected at considerable outlay. The sludge choked the pipes and pumps, and the labour and cost of the cloths for the presses were such that after a fair trial they were abandoned. Experiments with presses used in pressing beetroot in France, and others, also failed. It was then resolved to use the sludge filters, which had been successful in solidifying the sludge by Campbell's process at Wandsworth Road, and which small trials showed were applicable also to the sludge of Whitthread's process on account of its similar permeability. The filters were constructed in the cheapest possible manner, by forming the ground and draining its surface with agricultural drain pipes, surrounding the whole with a small earthen bank 2 feet high, and dividing the area into convenient compartments. The space was then filled with screened ashes, which were obtained gratis from the Local Board, to a minimum depth of 1 foot, and the sludge was run upon the top to a depth of about 12 inches. These filters were never constructed of sufficient extent, nor were they roofed over, on account of the financial difficulties which the Company encountered; but their working was quite satisfactory in fair weather, and enough experience was gained to show, that a total area of about 18,000 square feet, which would have cost £1,000 when roofed, would have sufficed to solidify the whole of the sludge as fast as it was precipitated, and would have reduced it so as to contain from 65 to 75 per cent. of moisture.

For the treatment and complete drying of the solidified sludge two of Milburn's drying machines, with beds 30 feet by 6 feet, were erected, and were in successful operation for several months. They would each turn out about 2 tons of marketable manure in twenty-four hours when fed with suitable sludge, with a consumption of coal in the furnaces equal to 1 lb. of coal for the evaporation of 5 lbs. of water, and they each required 1½ HP. to drive them.

It was found that the steam from the chimneys of these machines had an unpleasant odour, which required to be dealt with by burning or washing, but this improvement was not effected. It is to be regretted that the works were stopped, because experience established the feasibility of the process, its precise cost, the saleable quality of the manure produced. and apparently the certainty of its ultimate success. The result of several months' working was:—

Taking the sewage treated at 1¼ million gallons per day, the dose of dry chemicals used was 2 lbs. per 1,000 gallons.

The cost of the chemicals was £3 17*s.* 6*d.* per ton.

The cost of the manure per ton, dried, bagged, and loaded for sale, was—

	£.	*s.*	*d.*
Chemicals	1	14	2
Coals for drying	0	14	0
Labour	1	0	7
Actual cost of manure per ton	£3	8	9

This was the cost with insufficient appliances, and there is no doubt that it could have been reduced to £3 per ton if the works had been complete.

Compared with Crossness:—

	£.	*s.*	*d.*
Chemicals	1	14	2
Other expenses, as at Crossness	1	8	10
Total cost per ton	£3	3	0

The works were favourable for testing Milburn's machines. because no coals were used for other purposes. The actual cost of fuel was 14*s.* per ton of dried manure, which would have been reduced to about 10*s.* per ton if the sludge filters had been of sufficient area for the treatment of all the sludge. The cost of labour in drying was 15*s.* per ton, but was capable of reduction to 9*s.* per ton, making the total cost of drying 29*s.* per ton, but capable of reduction to 19*s.* It was also shown that there ought to be no loss of ammonia in Milburn's machines, with proper management and care.

The quantity of sludge produced was equal to about 32 tons of manure per week. It contained about 2 per cent. of ammonia, and 8 per cent. of phosphoric acid in precipitated phosphates, equal to 17 per cent. of tricalcic phosphate; which, taking ammonia at 18*s.* per unit, as before, and tricalcic phosphate at 2*s.* 6*d.* per unit, would give a value of £3 18*s.* 6*d.* per ton, exclusive of organic matter, about 30 units, and 5 units of potash, estimated to be worth another 5*s.* per ton. The value of the phosphate is believed to be higher, but even at this low figure the manure would pay the expense of manufacture and leave a margin. It appeared to meet with a ready sale, for it left the works as soon as it was made, and it was reported to have been bought largely in Holland and in Belgium, both for present and future delivery.

The Author believes that the effluent water bore out the favourable opinion of Mr. Hope, and of the eminent chemists who reported upon it. It was shown to be satisfactory by a letter from the Home Secretary to the Lee Conservancy Board, in which reference was made to the official inquiry of Lieutenant-Colonel Cox at Tottenham, on the 25th of May, 1875, when the conclusion was arrived at that the Tottenham Board had used the best known practical means of dealing with the sewage of the district.

It is unfortunate that the Company was compelled, by financial difficulties, to hand over the works to the Local Board, and that, partly owing to the doubt entertained as to the power of a local board to trade in the manufacture of manure, the Whitthread process has been for the present abandoned.

IV.—Conclusions.

However difficult, and even impossible, it may at present appear, there can be no doubt that any treatment of sewage which falls short of its profitable application in agriculture fails to solve the "sewage question." Precipitation is now generally believed to be unable to effect such a solution; yet it will hardly be disputed that it is capable of defecating sewage sufficiently to render it innocuous for discharge into the tideways of rivers, and capable also of clarifying it so as to increase the facility of dealing with it by filtration through land. The difficulty is to make the operation pay. This was abundantly shown by the Native Guano Company, when they proved at Crossness that their "extremely good effluent" cost £5 16*s.* 4*d.* per ton of the manure manufactured. Their experiment demonstrated that it was the bulk and consequent cost of the chemicals which caused the failure, and that the other expenses of their process, even with imperfect means of drying, were only about £1 10*s*. per ton, which amount was approximately the comparative cost also of Whitthread's process at Tottenham, where the quantity of chemicals used was much less. From what has been said it will be safe to conclude that the cost of a precipitation process, apart from chemicals, is constant in relation to the manure manufactured, and is about 30*s*. per ton of manure.

But if one process makes more manure than another from a given quantity of sewage, the cost of treating that sewage will be increased. Similarly, if one process makes more manure than another from the same sewage, the increase will be due to the greater bulk of the chemicals employed, and consequently the value of the manure obtained from the sewage will be proportionably enfeebled, unless the chemicals are of at least the same value as the matters in suspension in the sewage, or unless they arrest the manurial matters in solution. It follows that the cheapest process in first cost, and apart from the value of the manure, will be that which requires the smallest quantity of chemicals; and that the least possible working expense will be incurred when the chemicals cost nothing, and when they have no solidity, but are added to the sewage in the form of aqueous solutions or gases. The minimum cost of a dried portable manure would in that case be about 30*s*. per ton, or £6 8*s*. 7*d*. per million gallons of sewage, containing 70 grains of solid matter per gallon, capable of extraction.

The following tabulated statement of results already given shows the influence of the chemicals upon the cost of treating the sewage, the other expenses being the same in each case.

The sixth column shows the comparative outlay on each process.

Process.	Place.	Dose, per 1,000 Gallons.	Cost of Manure per Ton.	Actual Cost of treatment per 1,000,000 Gallons.	Ditto, reduced to Standard Sewage of 70 Grains per Gallon.	Quantity of Manure per 1,000,000 Gallons of Standard Sewage.
		lbs.	£. s. d.	£. s. d.	£. s. d.	Tons.
A B C . .	Crossness .	31·80	5 16 4	70 15 7	67 4 9	11·56
A B C . .	Leamington	1·86	1 17 1	15 18 0	9 16 2	5·29
Campbell .	Tottenham .	9·76	4 0 9	25 0 9	35 12 2	8·82
Whitthread.	Ditto . .	2·00	3 3 0	10 12 6	16 17 0	5·35
Assumed minimum	..	nil	1 8 10	..	6 8 7	4·46

The minimum cost of dry manure being about £1 8*s.* 10*d.* per ton, or £6 8*s.* 7*d.* per million gallons of sewage of the standard strength of 70 grains per gallon (equal to £2,350 per annum, or thereabouts, for a population of thirty thousand persons), two alternatives are open—to remove and not dry the sludge, and to recover the outlay by the sale of the dry manure. In the first case, if the cost of drying is saved, the expense of treating the sewage will be about one-third, or £2 2*s.* 10*d.* per million gallons of 70 grains per gallon, provided that the sludge can be removed free of charge. This will be equivalent to £780 per annum on a population of thirty thousand, or 6¼*d.* per head; and economy in working expenses, of the precipitation of such sewage, cannot be carried further than this. It may be considered as the limit of "cheap precipitation."

For the recovery of the outlay, it is obvious that sewage manure can have no greater value than that which it derives from the sewage. The question is, what is that value? The Native Guano Company fixed it arbitrarily at £3 10*s.* per ton, and actually made a market at Leamington at that price for manure which derived much of its bulk from the sewage of that place; and there is evidence of equivalent results, though the same manure was valued by the Rivers' Pollution Commissioners at £1 12*s.* per ton by analysis. But it has been already shown that a value only of £1 10*s.* per ton will cover the cost of the manure if the chemicals cost nothing, and the ammonia alone obtained from most sewage that is worth treating by precipitation will produce that amount. In short, the success of precipitation depends on neutralising the cost of the chemicals employed, or, in other words, upon the admixture of precipitants which have a manurial value, and upon the eventual recovery of that value in the dry manure.

Such a problem would be easy of solution were it not for some practical considerations, of which by far the most important is the capital required, not only for the initiation of a process which will perhaps necessarily be an expensive one, but for its continuance in full operation during the seasons when manure is less saleable, and until the demand becomes equal to the supply.

It is not surprising that local boards shrink from the responsibility of such a speculation, even though, under certain conditions, and in good hands, success might be assured; nor can they be blamed for having recourse to the alternative of seeking to reduce the cost of the chemicals to the lowest point by buying the cheapest, and employing the smallest quantity of them which will suffice to appease the River Conservancy Boards. Possibly private enterprise, which has done so much for this country, may again take the matter in hand, and, profiting by the experience of the past, may bring it to a successful issue. Meanwhile, precipitation is not in the hopeless condition which it is popularly supposed to be, and public bodies will do well to pause before they commit themselves to engagements to defray the entire expense of any process whatever. That which they should have done, and ought still to do, is to pay the minimum cost of £2 2*s.* 10*d.*, or thereabouts, per million gallons of sewage, and to require the owners of precipitation processes to pay the cost of their own chemicals, and of the conversion of the sludge into a dry manure. Such a course would reduce the public expense to the lowest point at present possible. It would, moreover, encourage private enterprise, and force the owners of processes to recover the value of the chemicals from the manufactured product, and would thus lead to a rapid solution of the "sewage problem," so far as that problem is capable of solution upon the principle of precipitation.

The Paper is accompanied by a series of diagrams, from which Plate 6 has been compiled.

APPENDIX.

PARTICULARS OF EXPERIMENTS WITH CAMPBELL'S PROCESS,

Supplied by the Secretary of Campbell's Patent Manure and Sewage Company, Limited.

1st Experiment, 16th of July, 1872, at Tottenham, treating 3,500,000 gallons of Raw Sewage.

Chemicals employed.

	£.	s.	d.
6½ tons bone ash, at £6 10*s.* =	42	5	0
4¾ ,, sulphuric acid, at £4 10*s.* =	21	7	0
4 ,, lime, at 12*s.* =	2	8	0
15¼ tons.	£66	0	0

Dry Manure obtained.

		£.	s.	d.
21 tons (24 tons in reality).				
Precipitated phosphate,	23·14 per cent., at 3*s.* 3*d.*	3	15	6
Insoluble ,,	3·80			
Ammonia	1·45, at 20*s.*	1	9	0
Sand	16·37			
Value of manure per ton is		£5	4	6

10,000,000 gallons treated on above basis show the following results:—

Chemicals required.

	£.	s.	d.
43 tons 11 cwt., costing	188	9	0

Manure obtained.

	£.	s.	d.
60 tons, at per ton £5 4*s.* 6*d.*	313	10	0
Deduct cost of chemicals	188	9	0
Left for working expenses	£125	1	0

2nd Experiment, 10th of December, 1873, at Wandsworth Road, treating 5,900 gallons of Raw Sewage.

Chemicals employed.

56 lbs. superphosphate.
16 ,, dry lime.

	£.	s.	d.
Total 72 lbs. chemicals, costing per ton	4	2	0

Dry Manure obtained, 112 *lbs.*

		£.	s.	d.
Precipitated phosphate,	21·66, at 3*s.* 3*d.*	3	10	5
Insoluble "	1·00			
Ammonia	0·935, at 20*s.*	0	18	7
Sand	28·60			
		£4	9	0

10,000,000 gallons treated on above basis show the following results :—

Chemicals required.

	£.	s.	d
54 tons 10 cwt., at per ton £4 2*s.*	223	9	0

Manure obtained.

	£.	s.	d.
84 tons 15 cwt., at per ton £4 9*s.*	377	3	0
Deduct cost of chemicals	223	9	0
Left for working expenses	£153	14	0

Chemicals cost £2 12*s.* 9*d.* per ton of manure.

3rd Experiment, 10th of April, 1874, at Wandsworth Road, treating 3,358 gallons of Raw Sewage.

Chemicals employed.

32 lbs. superphosphate.
9¾ " dry lime.

	£.	s.	d.
Total 41¾ lbs. chemicals, costing per ton	4	2	0

Dry Manure obtained, 56 *lbs.*

		£.	s.	d.
Precipitated phosphate,	21·87 per cent., at 3*s.* 3*d.*	3	11	1
Ammonia	1·31, " at 20*s.*	1	6	3
Sand	17·30			
Value of manure per ton		£4	17	4

10,000,000 gallons treated on above basis show the following results :—

Chemicals required.

	£.	s.	d.
55 tons 9 cwt., at per ton £4 2*s.*	227	7	0

Manure obtained.

	£.	s.	d.
74 tons 13 cwt., at per ton £4 17*s.* 4*d.*	363	6	0
Deduct cost of chemicals	227	7	0
Left for working expenses	£135	19	0

Chemicals cost £3 0*s.* 10*d.* per ton of manure.

4th EXPERIMENT, 12th of March, 1875, at WANDSWORTH ROAD, treating 33,724 gallons of Raw Sewage.

Chemicals employed.

36 lbs. superphosphate.
11 „ dry lime.

	£.	s.	d.
Total 47 lbs. chemicals, costing per ton	4	2	0

Dry Manure obtained, 80 *lbs.* 8 *oz.*

	£.	s.	d.
Precipitated phosphate, 15·87, at 3*s.* 3*d.*	2	11	7
Insoluble „ 3·0			
Ammonia . . . . . 1·17, at 20*s.*	1	3	5
Sand. . . . . . . 36·4			
Value of manure per ton	£3	15	0

10,000,000 gallons treated on above basis show the following results:—

Chemicals required.

	£.	s.	d.
56 tons 7 cwt., at per ton £4 2*s*.	231	0	0

Manure obtained.

	£.	s.	d.
96 tons 10 cwt., at per ton £3 15*s*..	361	17	6
Deduct cost of chemicals	231	0	0
Left for working expenses . .	£130	17	6

Chemicals cost £2 7*s.* 10*d.* per ton of manure.

MANURE PRODUCED from SEWAGE by TREATMENT with CAMPBELL'S PROCESS.

—	Experiment at Tottenham Works, July 16, 1872.		Experiment at Wandsworth Works, Dec. 10, 1873.	Experiment at Wandsworth Works, Apr. 10, 1874.	Experiment at Wandsworth Works, Mar. 12, 1875.	Total.	Average.
	Per cent.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Containing precipitated phosphates	23·14		21·66	21·87	15·87	82·54	20·63
" ammonia	1·45		0·935	1·31	1·17	4·865	1·216
	s. *d.*	£. *s.* *d.*	£. *s.* *d.*	£. *s.* *d.*	£. *s.* *d.*	£. *s.* *d.*	£. *s.* *d.*
Market value of phosphates per unit	3 3	3 15 6	3 10 5	3 11 1	2 11 7	13 8 7	3 7 1
" " ammonia "	20 0	1 9 0	0 18 7	1 6 3	1 3 5	4 17 3	1 4 4
Total	..	5 4 6	4 9 0	4 17 4	3 15 0	18 5 10	4 11 5

ANALYSIS of EFFLUENT WATERS PRODUCED by TREATING SEWAGE with CAMPBELL'S PROCESS.

Experiment	Nov. 22, 1873.	Jan. 13, 1874.	April 10, 1874.	March 12, 1875.
	Per cent.	Per cent.	Per cent.	Per cent.
Mineral matter in solution	41·76	35 52	38·72	46·40
Organic " "	5·92	15·04	13·44	10 56
Total solid contents per gallon, in grains	47·68	50·56	52·16	56·96
Free ammonia	2·952	4·02	5·03	4·34
Organic nitrogen	0·217	0·3488	0·2105	0·27
Mineral matter in suspension	None	None	None	None
Organic " "	"	"	"	"

TABLE SHOWING the PRICES CHARGED by the LEADING MANURE MANUFACTURERS and the GUARANTEED ANALYSES of such MANURES.

	Soluble Phosphates.	Ammonia.	Price per Ton. £.	s.	d.
1. E. Packard and Co., Ipswich	23·85	0·97	7	10	0
2. J. B. Lawes and Co. (Limited), London . . .	26·00	—	5	5	0
3. Odam, London	16·00	1·50	5	10	0
4. C. Tennant and Co., Carnoustie	26·72	1·23	7	10	0
5. " " "	25·00	—	6	0	0
6. Morris and Griffin, Wolverhampton	20·00 (8 to 10 insoluble)	—	7	0	0
7. Langdale's Chemical Co., Newcastle-on-Tyne . .	28·00	—	6	0	0
8. " " " .	25·00	1·25	7	10	0
9. " " "	14·00 (20 insoluble)	1·28	8	10	0
Nine manures, containing .	204·57	6·23	60	15	0
The average will be .	22·73	0·69	6	15	0

Valued at the same rate as Campbell's manure, viz., 3*s*. 3*d*. per unit of phosphates, and 20*s*. per unit of ammonia, the value of the average manure would be £4 7*s*. 8*d*.

[Mr. RAWSON,

Mr. RAWSON, the Managing Director of the Native Guano Company, or A B C process, said he had come as an invited guest to hear and learn, without any intention of speaking. But he could not allow a moment to pass without answering the attack on the A B C process made by Mr. Shelford. He had been exceedingly surprised to listen to such remarks, which came with bad grace from a gentleman who had been the Engineer at the Crossness works. If disposed to retaliate, or to give an excuse for some of the extra cost occurring there, he might do so by showing that it was not the chemical part of the process that had been entirely at fault, but that much might be attributed to the engineering department. He did not think the Author should have made use of information obtained as Engineer to the Company to attack the process in so public a manner. No doubt, at Crossness they were wanting in experience, and jumped at conclusions too quickly. They believed thoroughly in the process, but had brought it too early to a crucial test. They went to Crossness for a three months' trial. Unfortunately they had been misled as to the object of the Metropolitan Board of Works, by being required to work under the supervision of the Chemist of the Board, Mr. Keates, who drew samples every day. Either he or his son was on the spot almost daily. The Company believed, therefore, that the inquiry would turn on the sanitary results: and the consequence had been that their attention was devoted almost entirely to the chemical part of the process. Mr. Keates, in his official report, stated that the channel through which the effluent water passed was never cleaned during the three months, and did not show the slightest trace of sewage fungus. This would prove the degree of purity of the effluent water. They then asked to be allowed three months' further trial to show the commercial part of the process, but they were ordered off the premises, and it cost them £500 to remove the works. It was a great surprise to some of the Thames Conservators to find they were sent away, for they were at all events cleaning a portion of the sewage of London to the great satisfaction of the Conservancy. That, however, was in the infancy of the process; and it was of little interest to the Institution to hear what had been done in 1872. The question was what was being done in 1876; and the members would no doubt be glad to have the latest official report on the working of the A B C process on the 29th of February last, by the Sewage Committee of the Leeds Corporation:—

"Town Hall, Leeds, 29th Feb., 1876.

"The Utilisation of Sewage Committee of the Corporation of

Leeds having now had, with intervals, more than three years' experience of the working of the system of purification of sewage by the process of the Native Guano Company, hereby express themselves as well satisfied with the results obtained at the works at Knostrop (especially with the effluent) as compared with the result of any other system which we have tried. The sewage of Leeds, as is well known, is very difficult to treat on account of the numerous dyes and waste products which are mixed with the ordinary domestic sewage; the daily flow in dry weather is about thirteen millions of gallons; since the new works have been completed this quantity has been purified at an average cost of about £1 per hour for chemicals, or £1 17*s.* per million gallons; but, with a new description of alum, now about to be tried, and with charcoal prepared from the sludge, we confidently expect to be able to reduce the cost. On two recent occasions, samples of the effluent water were taken every few hours for a fortnight (the process being worked continuously day and night). These samples were mixed together and analysed by Dr. Letheby, whose reports show that the water is fit to be turned into any river.

"The sludge has not yet been converted by us into a saleable manure; but four drying cylinders are just ready for use, and will at once be set to work. It remains to be proved whether the sale of the manure will pay for the expenses incurred in the manufacture, but from replies received from many farmers and gardeners who have used some manufactured at the experimental works, it appears to be well suited for grass land, garden produce, plants, and flowers.

"Up to the present time we know of no system more likely to answer our requirements; and if the manure is saleable at £1 per ton, it will pay expenses. Our own trial on grass land at Knostrop shows the value to be £3 10*s.* per ton as compared with Peruvian guano at £15.

"Signed on behalf of the Committee,
"GEORGE TATHAM, *Chairman.*"

The sewage of Leeds was of a most extraordinary character, changing at all hours of the day from green to blue, and from blue to black; yet the effluent water was as bright—he did not say as pure—as a mountain stream, and was fit to go into any river. According to Mr. Tatham's report, if the manure could be sold at £1 a ton it would pay all expenses. The company had sold more than 4,700 tons of native guano at an average price of nearly £3 10*s.* a ton, and the farmers who had begun with 5 tons or 10 tons, came to Leamington for 50 tons, 100 tons, and even 200 tons. He did not attempt to explain why the manure, which he admitted did not yield on analysis high results according to the ideas of agricultural chemists, was worth so much money; but that it produced good crops was the experience of hundreds of farmers whose testimonials had been published, and whose names and addresses were given, so that their reports could be easily verified.

Mr. GRINDLE complained that neither the Lime process nor the Phosphate sewage process had been mentioned. The latter process, he believed, was about the only one that dealt with the sewage of towns entirely, and sold it at a profit. It had been in operation for twenty months at Hertford, and had given entire satisfaction. Twelve or fifteen months ago the Lee Conservators, on receiving a complaint from below Hertford, had an analysis made; and Mr. Keates stated that the effluent water was such as might be allowed to run into any river.

Dr. VOELCKER said that the disposal of the excreta of towns was indeed a gigantic undertaking, and it was far too wide a subject to be treated in the time at his command. The difficulties in the way of removing the sewage of towns were admitted on all hands, but they were greatly increased when the excreta were plunged in water instead of having them pure and simple. The cheapest mode of dealing with town refuse was to carry it as produced direct to the land—a method adopted in Flanders and in some parts of Germany. He wished to disabuse the minds of some sanguine persons of the idea (which he believed was gradually losing ground) that money could be made by human excrements. He could not share the opinion expressed by Mr. Redgrave, although he believed that from urine valuable products, such as ammonia salts, might be extracted, leaving a slight profit to the manufacturer; but against this should be placed the loss which was experienced in the manufacture of the solid excreta into dry and portable manures. He knew of no process, nor did he believe that any such existed, by which these could be profitably converted into portable manures. Some years ago he travelled all over Belgium with a view of getting special information from the town authorities, who had the disposal of sewage matters entirely in their own hands; and he found that there was not a single place, though the excreta were collected most carefully and undiluted with any slops, where more than 1 franc per head was realised, and in most places the town authorities had to pay for the collection and removal to the country. Some years ago, also, a commission had been appointed by the Prussian Government, and it ascertained that there was not a single town in Germany in which a profitable return was made for the disposal of the sewage, and in most places the authorities had to pay for the removal. If this was the case with the excreta unmixed with ashes or slops, it was obvious that the expense must be vastly increased when they were diluted with an immense quantity of water. He could not understand how, by Mr. Campbell's process, in the treatment of 10,000,000 gallons of sewage, the sale of the manure produced could leave for working expenses £125. Before criticising the figures a little more closely, he wished to point out two practical mistakes that had been made. The precipitated phosphates were set down at 3*s.* 3*d.*; that was the price of soluble phosphate, but the value of precipitated phosphates was 1*s.* less than of phosphates actually soluble in water, which of course would make a considerable difference in the final result. Then, again, ammonia was set down at 20*s.* In sulphate of ammonia, however, ammonia could be bought for 16*s.* per unit per cent. But that was not all: the sewage precipitated, whether by the superphosphate process, or by Messrs. Forbes and Price's process, or any other, did not contain actual ammonia, but organic matters yielding ammonia very gradually. The precipitation did not remove any ready-formed ammonia. Only the suspended organic matters which contained nitrogen were collected, and that nitrogen was put down in the estimates as ammonia. In that shape the commercial value of the ammonia was very different from its value in the shape of ammoniacal salts. Even 15*s.* per unit would be a high estimate; and that again would materially reduce the value of the manure produced. So that instead of £5 5*s.*, a more correct estimate perhaps would be £4 4*s.* per ton. Then there was another matter which he could not quite understand from the figures given. Assuming the figures to be correct, and taking the ammonia at 20*s.*, the manure produced from 10,000,000 gallons of sewage was 60 tons; the value of the ammonia in 1 ton was given at £1 9*s.*, bringing up the value of the ammonia in 60 tons of manure to £87. It was well known that by using a precipitating agent like superphosphate and lime, not a particle more of phosphoric acid was produced from the sewage than was actually thrown into it. Indeed, he did not believe that the full quantity thrown in could be got out again. The total benefit of precipitation arose from the removal of the suspended organic matter containing nitrogen; or, to express it briefly, its ultimate utilisation as ammonia, which was worth, according to the statement, £87. The cost of the superphosphate required was put at £188 9*s.*; adding to that the value of the ammonia, the total value of the manure that ought to be produced was £275 9*s.* But in the estimate the value was given at £313 10*s.*, showing a difference of £38 1*s.* He did not understand how the value could be possibly increased, indeed the opposite was the case. As he had already stated, the value of soluble phosphate was reduced 1*s.* for each per cent. in becoming precipitated. The manure, according to the statement, contained 23 per cent. of precipitated phosphates, which would give a reduction of 23*s.* per ton; or for the 60 tons of manure produced the reduction in value would be £63. He had taken the original value of the chemicals themselves, without making any allowance for the fact that they were immersed in water, and then had to be dried again. Allowing £87 as the value of the nitrogenous matter precipitated from 10,000,000 gallons of sewage, and deducting from that sum £63 for reduction in the value of the soluble phosphates in becoming precipitated, there remained for working expenses only £24, and not £125 1*s.* But the value of the nitrogenous sewage matter, calculated on the basis of 15*s.* per unit ammonia (and even at that price they would be dear), was only £65 5*s.*; consequently there remained a margin of only £2 5*s.* for working expenses. Mr. Shelford stated that the cost of the precipitation process, apart from the chemicals, was about 30*s.* per ton; therefore 60 tons would entail an expense of £90. If the town authorities gave a subsidy of only £2 2*s.* 10*d.*, or say £2 3*s.* for a million gallons of sewage, that would amount to £21 10*s.*, and deducting that from the cost of production, £90, there would remain a deficit of £68 10*s.* for every 60 tons of manure produced, or the manufacture of every ton of manure would entail a loss of £1 2*s.* 10*d.* It was no wonder, therefore, that speculations in sewage companies and precipitation processes of every kind could not possibly pay, unless the town authorities made up their minds to put their hands deeply into their pockets.

Mr. C. WALFORD remarked that he had been struck, as an amateur, by the absence of any mention of Dr. Anderson's process. It had been stated that the difficulty of precipitation processes was the cost of the chemicals. The essential ingredient of Dr. Anderson's process was shale, which he obtained at a small cost, so that difficulty had been overcome. He hoped the method would have a fair trial, and believed it would hold its own against any that had been mentioned.

Mr. E. MEYERSTEIN said, Dr. Voelcker professed to point out two practical mistakes in the Appendix to Mr. Shelford's Paper, and one of them he tried to prove by giving the value of precipitated phosphates as only 2*s.* 3*d.* per unit, or 1*s.* less than that of soluble phosphates. The reason assigned for the less value of precipitated phosphates was that they were not so assimilable or serviceable for plants. That might be Dr. Voelcker's opinion, but it was not shared by other chemists of standing and learning, and it was certainly at variance with the report sent by him to the Phosphate Sewage Company, which, after giving an analysis of a sample of the manure produced by the Phosphate Sewage Company's process stated, "The whole of the phosphoric acid, I may state, occurs in this manure in the shape of precipitated phosphate, a form, I need hardly say, in which the phosphates are readily available by plants. Being obtained by precipitation from their solution, the phosphates are present in the deposit in a very efficacious form."

A chemist of acknowledged authority in agricultural matters, Mr. Frederic A. Manning, reported about precipitated phosphates, "The manure, the analysis of which I append, is evidently a precipitated phosphate of lime, and is therefore in a finely divided state, and readily assimilable by plants, although not actually soluble in water. All soluble phosphates of lime, on mixing with the soil, are immediately converted into the insoluble or precipitated form; it follows, therefore, that the manure is but little inferior in agricultural value to the superphosphates of lime in the market of the same percentage composition. The cost of soluble phosphates to farmers is about 4*s.* per unit per ton. . . . . The value of precipitated phosphate, though less than that of soluble phosphate, is certainly higher than that of guano. I think, therefore, that 3*s.* 3*d.* per unit per ton is a fair valuation of precipitated phosphate."

The well-known analyst Mr. Alfred Sibson, wrote on the same subject, "Having issued a scale for the valuation of manures, I make it a rule not to give the money value of the manures I report upon. It will be seen, however, from the values I have given, viz., 3*s.* per unit for precipitated phosphates, and 20*s.* for ammonia, that a manure of the composition analysed by me will be of a fair market value."

Before compiling the tables in the Appendix to Mr. Shelford's Paper, he consulted several gentlemen capable of forming an opinion, and as their estimates of the value of precipitated phosphates varied from 3*s.* to 4*s.* per unit, for the purpose of being within the mark he adopted 3*s.* 3*d.* as the basis.

The next practical mistake Dr. Voelcker had pointed out was that ammonia according to his theory was worth not 20*s.*, but in the state in which it existed in Campbell's manure 15*s.* per unit. But how was it that in an analysis furnished by Dr. Voelcker to the Phosphate Sewage Company he gave the equivalent of the organic matter in ammonia? He stated, "Organic matter and water of combination, 20·11. Containing nitrogen, 0·57—equal to ammonia, 0·69." How was it, if he valued precipitated phosphates at only 2*s.* 3*d.* and ammonia at 15*s.* per unit, that in the same report he wrote as follows: "The sample analysed by me contains an amount of precipitated phosphate which is equivalent to 62 per cent. of tribasic phosphate of lime, and an appreciable amount of nitrogenous organic matter capable of yielding 0·69 per cent. of ammonia. It possesses valuable fertilising properties, and, in my opinion, a sewage manure equal to the sample analysed by me will command a ready sale at £7 7*s.* per ton."[1]

It should be borne in mind that the phosphate contained in the manure produced by the Phosphate Sewage Company was not phosphate of lime, but phosphate of alumina, which was on all hands admitted to be next to worthless for agricultural purposes. Yet Dr. Voelcker reported not only that the manure containing no other fertilising matter than 0·69 per cent. of ammonia was worth £7 7*s.* per ton, but he added that it would command a ready sale at that price. Dr. Voelcker had had too much experience in issuing reports not to be careful in drawing up such documents; and since the estimated valuations in the Appendix were much below those put by Dr. Voelcker upon the constituents of the Phosphate Sewage Company's manure, he certainly ought not to impeach their correctness. The valuation of the various manures mentioned in the last table of the Appendix was on the same basis as that of Mr. Dugald Campbell's manure; the comparison drawn was therefore a fair, just, and correct one. Dr. Voelcker had said it was well known that, by using a precipitating agent like superphosphate of lime, not a particle more of phosphoric acid was produced from the sewage than was actually thrown into it, and he did not believe that the full quantity thrown in could be got out again. No attempt had been made to substantiate the assertion, nor had he even taken the trouble to witness any experiment in connection with that process, nor did he profess to have devoted much time to the study of sewage experiments. When speaking of sewage at a meeting of the Society of Arts, on the 6th of December, 1871, Dr. Voelcker, according to the report of the Society's "Journal," made the following statement: "His name had been mentioned in connection with the phosphate sewage process. He would mention that he had nowhere expressed any opinion upon the commercial bearing of this matter, but merely that the phosphate

[1] *Vide* "Chemical News," March 10th, 1871.

sewage process patented by Dr. Forbes so far purified the sewage, if carefully practised, that the water was admissible into a stream of running water."[1]

In conclusion, Mr. Meyerstein remarked, that the least costly was not always the cheapest mode of doing things. If the sewage of a town could be purified, without the aid of chemicals, at a cost of £1 8*s*. 10*d*. per ton of dry deposit—which he believed was the lowest estimate given in Mr. Shelford's Paper—that cost and the cost of removing the deposit would have to be borne entirely by the ratepayers; for, devoid of any fertilising constituents, the deposit could certainly not be sold. Farmers had learnt that it was cheaper to buy manure of a high percentage of fertilising ingredients than a low-priced article, for on the latter they had to pay so much more for carriage and for applying it to the land. Did it not stand to reason that if a saleable manure could be produced by the admixture of certain chemicals to sewage, even assuming that it did not leave a profit—which he maintained it did—it would relieve the ratepayers of a heavy burden?

He thought he had said enough to prove that the figures given in the Appendix were justified, and that Dr. Voelcker's strictures were certainly not merited.

General Scott believed that nearly all that could be said on the subject had been said; yet such discussions were important in educating the public up to the point of insisting that the knowledge possessed should be taken advantage of. During the last three or four years a great change had taken place in the views of town councils with reference to the disposal of sewage matter. They formerly believed that they had in sewage a material which was saleable at a profit, but they had now discovered not only that it was valueless, but that they must be at considerable expense in removing it. The first question he should ask, if consulted as to the best mode of getting rid of water-carried sewage, would be, "Are you near enough to the sea to get rid of it in that way?" In regard to "dry sewage" they were on somewhat different ground. He was not of Dr. Voelcker's opinion, that no benefit could be derived from turning it into a concentrated manure. Many would, no doubt, say that the dry-sewage system was entirely a mistake; but the fact could not be got rid of, that a large proportion of the manufacturing population of the country made use of cesspools, pails, or some other convenience of the kind. That being so, and many town councils refusing to adopt a water-carriage system, it

[1] *Vide* Journal of the Society of Arts, vol. xx., p. 69.

became the duty of engineers to endeavour, at all events, to reduce the expense of dealing with dry sewage. A few years ago the ordinary excreta of towns, mixed with ashes, realised in some cases 4*s.* or 5*s.* per ton; by degrees the manure was reduced to 1*s.* and 1*s.* 6*d.*, and then to 5*d.*, and in many cases there was now a difficulty in getting rid of it. In many towns it was a common practice to "tip" it, and then build houses upon it. That certainly was an expensive method of dealing with it, for it was most costly to human life; and it would be better, even at a pecuniary loss, to turn the sewage into a concentrated manure. He believed that, by giving attention to the subject, much might be added to the comfort of the people and to the value of the produce. He had never used one of the pails introduced by Mr. Alderman Taylor (to whom the country was much indebted for the Rochdale system); but he had been given to understand that disagreeable consequences from splashing sometimes ensued. An obvious remedy would be to allow the liquid to run into another receptacle. Dr. Voelcker, while believing it to be useless to attempt to get any value out of the solids, said that some small advantage might be derived from manipulating the liquids. If the solids and liquids were allowed to mix and to be shaken up in the cartage, the subsequent separation was a difficult matter. It might not be possible, by any known method, to derive a money value from dry sewage, but every year it became more and more difficult to deal with it mixed, as it formerly was, with ashes; and the most economical plan would ultimately be to convert it into a concentrated manure. Besides, it was possible, though not probable, that the importation of foreign guano might be cut off through war, when it might be desirable to use home-made guano. He would not trouble the members with any details of the plan he had devised with a view of extracting ammonia from urine, but Mr. Redgrave had exhibited some bottles exemplifying the results of the process.

With reference to water-carried sewage, he quite concurred in the statement of Mr. Shelford, that in the precipitation of sewage the cheapest material should be used. He did not, however, think that bone phosphate was the cheapest, but nevertheless phosphoric acid might be employed under certain conditions with advantage. In some of the northern towns, for instance, where muriatic acid could be obtained at a cheap rate, and phosphates were also readily procurable, it was possible that by a judicious use of these materials some advantage might be gained, but he thought no such advantage could be obtained by precipitation, as recommended by Mr. Shelford. A material was employed in the process worth £5 or £6 a ton, and it was converted into a material worth only £3 or £4 a ton. He admitted that if it could be readily sold as manure for £3 or £4 a ton, it might answer well, because a certain amount of nitrogen could be obtained from sewage water; but the tendency of farmers was to buy higher classes of manures, and it would be impossible to dispose of large quantities of manures of this low value. The difficulties in the way of turning out a valuable manure, in the manner proposed by Mr. Shelford, arose from the foreign elements present in the sewage. There was a quantity of detritus in town sewage, and, owing to the large quantity of lime required to neutralise the acid of the precipitant, there was also mixed with the deposit a large quantity of carbonate of lime, which further degraded its value. In one of the first experiments made by the Phosphate Sewage Company, there was, according to an analysis by Dr. Voelcker, as much as 50 per cent. of carbonate of lime precipitated. It appeared to him that the solid matters should be allowed to subside first as far as they would, and be dealt with separately; then the lime should be added to the sewage water, to precipitate the carbonic acid; and, thirdly, to the limed effluent sewage-water should be added the solution of phosphate, each operation being conducted in a separate tank. In that way the phosphate of lime might be obtained separated from the carbonate of lime and the silicious matters. Practically, in that way he had been able to obtain in the third tank a manure worth about £7 a ton, because the phosphate of lime in the act of precipitation carried down a considerable quantity of nitrogen from the sewage water, which added considerably to its value. But such a plan was only practicable when both phosphates and acids were very cheap. With regard to the first deposit, consisting of silicious matters mixed with organic matter, they might be dealt with separately as an inferior class of manure; they would be small in quantity as compared with what they would be if mixed with the other precipitated matters, and it was easy to deodorise them by a small addition of lime. Even 2 or 3 per cent. of lime mixed with sludge was sufficient to deodorise it. The second deposit, consisting chiefly of carbonate of lime, could be calcined and be re-used. He had carried on the process of re-using as many as six times, and still found that the lime precipitated very well. Such a process of phosphate precipitation might be feasible in manufacturing towns in the North; but in other cases, where the ocean was not at hand to receive the sewage, he believed that the cheapest way of dealing with it would be by precipitating it first with lime only, and then, when the Legislature required that a further purification should be carried out, the clarified sewage water could be passed through a small quantity of land, to filter and cleanse it thoroughly.

Mr. Alderman TAYLOR, of Rochdale, considered it disgraceful that a civilised community should be now discussing "How to do it," or rather, as he thought, "How not to do it." Town councils had been learning in the dear school of experience. Rochdale had been trying the pail and manufacturing system, but a clamour was raised by some persons who thought it a failure, and the committee consequently recommended that the manufacturing should be discontinued for twelve months. That was accordingly done, but the result was so disastrous that they were now going to revert to the former system. There really was no difficulty in the use of pails in Rochdale, so far as offensiveness was concerned. Last year the number of pails used was 4,741, this year 5,566, no compulsion whatever having been employed by the town council; it was a voluntary thing on the part of the owners, who had abandoned the old midden-closets, and in many instances water-closets. This showed that the pail system was appreciated by the inhabitants. He did not wish to be understood as recommending the dry system only. No one advocated more thoroughly than himself the process of irrigation; but he advocated with equal earnestness the keeping out of the sewers of all excreta and urine. Whenever the water-closet system was used, the value of all sewage was weakened to the extent of fully one-half, notwithstanding the admission of excreta and urine. In water-closet towns the quantity of water consumed per head was almost double, and the sewage was so greatly weakened that it became necessary to buy more land. The great difficulty was to get land at a fair market price. If landowners were not so intent upon levying blackmail upon towns, there would be no difficulty in dealing with the sewage question; and if other towns would profit by the example of Rochdale, and the valuable hints of General Scott, they would not only be able to collect and distribute the excreta and the sewage, but to do so with a profit. He did not agree with Mr. Redgrave that it was possible, by a modification of the midden-closet system, to effect a removal without offensiveness and injury to health. Offensiveness had nowhere been avoided except by the adoption of pails. He agreed as to the advantage of separating the liquid and solid matters, but not precisely in the manner pointed out. He also concurred in the suggestion that the removal of excreta and ashes should be carried on by the local authorities under stringent supervision. The town council of Rochdale had recently passed a resolution abolishing "tips." There would be extreme difficulty in carrying out the resolution, but they were determined to do it; and he believed that the refuse of towns might, if properly used, be made profitable. They now utilised nearly all their refuse. The calculation had been made for the year just ended, showing that the cost to the town, when the manufacturing system was not adopted, was between £1,000 and £2,000 more than it was under that system. If they manufactured, and did not dispose of any of it, it was found to be cheaper than selling the matter in its crude state, for the carriage of the crude manure exceeded by some shillings per ton the amount received for it. On the other hand, of the manufactured manure, this year they had sold 2,140 tons, being an increase of 140 tons over the previous year. The amount received for the manure was £2,380, a tolerable income for a material said by some to be worthless. He believed that a much larger sum would ultimately be realised, and he hoped that, instead of the manure being worth £1, it would realise £2, £3, or even £4 per ton. They were able to use their refuse even to the finest ash. He did not like the idea to go abroad that the ashes should be thrown away. In all fine ash there was at least 6 per cent. of sulphuric acid, and a certain amount of phosphoric acid; so that it was not altogether worthless. It was far better so to use the material than to allow it to be thrown into "tips" and be built upon. It had been the custom to throw away refuse and build afterwards upon it. One local board, near Rochdale, gave £100 a year for a place of that kind, which would certainly be built upon within thirty years; and it was disgraceful that such a thing should be allowed. The report of the Rivers' Pollution Commissioners ought to convince every one that for manurial processes sewage irrigation was the only plan to be adopted. That was for sewage proper, but not for excreta. With regard to the remark of Mr. Redgrave, that the Goux system was the forerunner of the system adopted in Rochdale, he wished to observe that Rochdale was really the forerunner in the matter. In 1865 he himself wrote to the scavenging committee, detailing almost the very plan now practised. They tried the Goux system as it was patented, and it failed, and the advocates of that system then adopted the method employed at Rochdale, so far as collecting was concerned. He believed that Rochdale had got over many of the difficulties of former days, and that in a short time it would adopt irrigation, if only land could be obtained at a reasonable price. He hoped both systems would be carried out as he had suggested, so that waste might be avoided and a gain secured.

Mr. Melliss desired to bring under notice the process known as Dr. Anderson's—the sulphate of alumina and lime process, which had been in operation during the last three years at Nuneaton, and during the last two years in Coventry. In the latter town every gallon of sewage was purified under the strict supervision of the officers of the Corporation. The town contained forty thousand inhabitants; the sewage was very foul, being mixed with manufacturing refuse from dye and varnish works; the number of water-closets was about five thousand. It was often supposed, in regard to purification by chemical precipitation, that the most difficult thing was to get a purified effluent water. That was no doubt true to some extent, but the greatest difficulty was how to get rid of the solid matter. This rendered the Lime, Campbell's, and some other processes impracticable. Birmingham had been held up in "The Times" as an example to be followed, but the process adopted there was a complete failure. In the first place, the effluent water was procured by treatment with lime, and lime-water, it was well known, would kill fish or any other animal life. In the next place, the Corporation did not know what to do with the deposit. They had 220 acres of land in which to bury it, but that could not last long. It appeared from Mr. Shelford's description of Mr. Campbell's process that, in dealing at Tottenham with 3½ million gallons of sewage, 15¼ tons of chemicals were used. The yield of dry manure was 22 tons, equal to 132 tons of sludge. According to that proportion, the quantity of chemicals required for such a town as Leeds would be 53 tons per day. Adding that to the sewage, there would be about 500 tons of sludge to dispose of daily. At Coventry 2¼ million gallons of sewage were treated daily; 15 cwt. only of solid chemicals were put in, and 4½ tons of dry manure were obtained, or 25 tons of sludge. At Birmingham 17½ million gallons were treated daily, 14 tons of lime were put in, yielding 400 tons of sludge, representing 66 tons of dry manure. It was obvious that the less solid matter put in, the easier it was to get rid of the sludge; and there could be no doubt that precipitation processes had hitherto been greatly hindered by this difficulty. It appeared from the Report of the Royal Commissioner on the purification of the Clyde,[1] that the solid matter or manure estimated to arise from the sewage of Glasgow amounted to between 400,000 and 500,000 tons annually; but, according to the experience at Coventry, the actual solid matter that ought to be produced was only 40,000 tons. Precipitation was said to be an expensive process, but it was not so when properly managed. The cost of purifying 2¼ million gallons of sewage

[1] *Vide* Report of Sir John Hawkshaw, p. xi.

a day at Coventry, reckoning no sale of manure, was 1*s.* 7*d.* per head per annum; the cost at Merthyr Tydvil was 1*s.* 8¾*d.*; at Leamington 1*s.* 6½*d.*; at Warwick 3*s.*; at Banbury 1*s.* 7*d.*; at Northampton 1*s.* 8¼*d.*; at Tunbridge Wells 5*s.* 3*d.*; at Norwich 3*s.* 6*d.*; at Croydon 2*s.* 1½*d.*; at Kendal 1*s.* 2¼*d.*; at Eton 5*s.* 1½*d.*; at Swindon New Town 3*s.* 7¾*d.* These amounts included the purchase and preparation of the land, and the main outfall sewer, when it was at a considerable distance.

Lieut.-Colonel Jones, V.C., was glad to find it stated that the dry system was chiefly applicable to places in which there were natural local impediments to the use of water as a carrier. As a sewage farmer he believed that water carriage, wherever it was applicable, was the best and most satisfactory method to adopt. But he was so far free from prejudice that, on the sewage farm which he cultivated, he used nothing but earth-closets for deodorising and getting rid of the fæcal matter produced on the premises. Under certain conditions that was perhaps, in a sanitary point of view, the most satisfactory method of dealing with the subject. The most important of these conditions was the efficiency and the daily superintendence of the labour required in supplying earth and removing manure—a condition which it was difficult to attain on a large scale. There should also be plenty of store room under cover to protect the dry earth from the fluctuations of the weather, and to protect the manure during the interval between its appearance in the closets and its removal to be dug into the land. Under such circumstances, and where the necessary water for water-closets would have to be pumped from a deep well, there was good reason for adopting the dry-earth or ash-closet system. But, after all, there were the slops and kitchen refuse, and manufacturing liquids, to be removed from large towns; and if there were a properly constructed sewer to take that refuse away as quickly as possible, he saw no reason, in a sanitary point of view, why the fæcal matter should not go with it, because he maintained that it ought to be immediately removed, together with everything foul, to the outfall, and spread upon the land. That was not an occasion to enter into a discussion with regard to the utilisation of liquid sewage, but he hoped at the forthcoming Sewage Conference to be able to show that a sewage farm, conducted under reasonably fair conditions, even where the rent of land was £5 an acre, could be carried on at a satisfactory profit. With regard to the valuations of precipitates in the second Paper, reference was made solely to the standard of theoretical value. He always endeavoured to reconcile theory and practice; and when practical results did not follow, he was led to believe that there was a mistake either in the theory or in the mode of its application. In the present circumstances he had no doubt that the mistake was in the application. The theoretical value of ammonia was pretty well established, but that standard was only applicable within certain limits, namely, with a percentage of from 10 to 15 per cent. of ammonia, which might be fairly compared. In regard to the comparison of manure with 1 or 2 per cent. of ammonia with manure containing 12 or 13 per cent., any wise farmer would prefer to buy the more expensive article, having the least bulk, because of the cost of carriage, and of spreading the manure upon the land. Even if the manure was delivered and spread upon his fields free of expense, he would prefer to have guano, because the texture of the soil might be spoiled by the additional carting required for the other.

Mr. HAVILAND said, as a Medical Officer of Health over a large area in Northamptonshire, he often found himself in a difficulty in regard to the disposal of sewage. In 1874 he had recommended the authorities to take into consideration the different modes adopted, and he had himself made a tour of inspection with that view. He visited Aldershot, where the Goux system was adopted, and Halifax, where it was first applied in the autumn of 1870, to see its results in the case of a large town. The Registrar-General had given him permission to investigate the mortuary returns in that town for the last six years, 1870–5, during which there was an average of 25 closets per thousand inhabitants. These returns included two trienniums, during the first of which (1870–2) the rate of mortality was increasing. From 1866 to 1871 it had increased rapidly: in 1869 it had risen to twenty-six per thousand, and in 1871 to thirty-one. In the first triennium there were no wards with a mortality above the average, only two wards with a mortality from all diseases below the average, and only three with a mortality from fevers below the average. That was at a time when the Goux system was only partially carried out, the number of closets being 14 per thousand. In the second triennium, when the number of closets was 37·6 per thousand (there being only two wards below the average), there were six wards out of the ten with a mortality from all diseases below the average, twenty-six to every thousand persons; and in regard to fever mortality, only two wards were above the average. If these results were not altogether to be attributed to the adoption of the Goux system, he could not help thinking that something should be attributed to the sanitary action which took place under that system. He had under his medical charge three hundred and sixty-five towns and villages, and, from practical experience, he believed three things were essential—scavengering, the dry-sewage system, and a place to put it; a "muck-acre," from which to remove the manure to the land. So far as he had seen, the Goux system offered the greatest benefit, removing as it did many of the difficulties with which he had had to contend. He might mention that Halifax, from its hilly character and the difficulty of carting, was a troublesome place to deal with; and yet the results had been such as he had described.

Mr. ALFD. M. FOWLER said, in Salford seven systems were at work. With reference to the method carried out at Rochdale, it should be remembered that that town was on a tributary of the Irwell. He had had twenty-five years' experience in connection with the sewage of towns, and he knew that in Leeds, where he had been Engineer, the cost of collecting, with the box system, was 9*s.* 3½*d.* per ton in a ward of fifteen thousand inhabitants, where the depôt adjoined the river, so that there was no distance to cart the material. The amount received for it was not more than 1*s.* or 2*s.* a ton. The total cost for collecting in the ward was £1,800 a year, and the total cost in the borough was £21,000. Besides that, the liquid sewage was still on its way to the sewers. Tanks had been constructed, designed by himself, and it cost the authorities £15,000 a year for chemicals alone. That was a town under a Chancery injunction; and Rochdale would perhaps have the same thing by-and-by. He was now constructing a sewer in Salford, at a cost of about £100,000, to guard against the difficulties of the Court of Chancery, and the Corporation had purchased 40 acres of land for the same purpose. Was it likely, under such circumstances, that Rochdale would be allowed to pour its sewage into the Irwell? Certainly not. The theoretical value of manure had never yet been realised. In dealing with the sewage of a town, it was absolutely necessary to put down nearly 1*s.* in the pound for it; and it was simply fencing with the matter not to do so. It would cost 6*d.* in the pound to deal with the sewage properly, and the sooner the work was set about the better. Leeds was setting about it boldly. He did not know that they had sold their manure. They had advertised the use of the works in the principal papers in the country, and offered every facility for experimenting at the works. Several persons had tried experiments there, but without any useful result. A contract had been previously entered into with the A B C Company. That enthusiastic body set a fictitious value upon the manure; it therefore went to the ground, and the contract had been cancelled.

They again, however, sent for the company, believing it was the best thing to do. He had taken samples of the effluent from the sewage water, in which the fish thrived better than in the water supplied to the town. Where the tub system could not provide for the collecting of liquid sewage, it was far better and cheaper in the end to turn the refuse into the sewer. If all the excreta were kept out of the sewers, not an acre less irrigation land would be required, and not an inch less depth would be needed in the tanks. The refuse of bedrooms, liquid sewage, &c., should all go into the sewers. The country was alive to the question of the pollution of rivers, and it was absolutely necessary that the subject should be dealt with. He believed that Leeds would save £14,000 per year if all the refuse could be turned into the sewers at once. If it all went down to the outfall, it could be dealt with in the usual way by the A B C process. It had been proved by Professor Frankland that the water flowing from the tanks at Wrigley's works, having been taken from the river Roach, was actually purer than the best supply to London from the Thames. The universal supply of water-closets throughout the country was, he thought, the true solution of the sewage difficulty. In Salford he had designed a water-closet that utilised the whole of the refuse water from the house in passing the fæcal matter into the sewers, so that no town water supply was required. Fifty of them had been made, and they acted so satisfactorily that every engineer who had seen them approved them.

Mr. Alfred Smee considered the time had arrived when fixed principles should be adopted to determine how to deal with sewage. Two Papers were under discussion, one dealing with what might be termed the dry method, which would only be used when the wet process could not be adopted. Two difficulties in the dry-earth process had not been adverted to: one, the difficulty of supplying dry earth; the other, the extra cost which would be entailed on the community if the ashes of the house were used as a disinfectant. At present they were employed in brickmaking, and he was assured that the cost of houses would be sensibly increased if all the ashes were used as disinfectants, however admirably they might be adapted for that purpose. But in every large town the common verdict of mankind was to have a water-carrying system. The water-closet system, however, must be carried out with great perfection. When water entered houses, from howsoever pure a source, and passed through to become sewage, it immediately became noxious, and should be disinfected at the earliest possible moment. Taking that as an initial principle, the question arose as to the process of precipitation of fæcal matter, for in fæcal matters there were many products, such as mucus, eminently calculated by nature to resist the operation of water. Mucus, as in the case of frogs' spawn and the covering of fish spawn, was a substance particularly capable of resisting water, and unless it was precipitated it was liable to generate diseases. He need hardly direct attention, from a medical point of view, to the way in which the mucus of gonorrhœa might be propagated to the eye and to other membranes, or how typhoid mucus might be propagated if taken into the system. It was therefore important that the matter which passed into the sewage should be precipitated, thrown down, and destroyed at the earliest possible moment. One of the great points in the discussion was how to precipitate that mucus. The fæcal matter might be precipitated either by lime, by alumina, by the salts of alumina, or by animal charcoal, then by soluble phosphates, or by a host of other similar substances; but none of those substances were perfect, and the urea was left unprecipitated in a solution of water. Having got sewage with the fæcal matter precipitated, it would be conceded as a principle that it might be beneficially given to a thirsty plant, that was to say, to a plant in a condition to take water. If one drop more water were added to that plant than it could take, then the plant would be damaged, its functions injured, and its products bad; and he would challenge any one present to say that there was any sewage farm, carried out continually and persistently, that was doing all the good it might to the plants upon that farm, but was not actually doing a positive mischief. Those general principles showed this, that the sooner the noxious elements of sewage were decomposed and destroyed the better. The next proposition, enunciated by one of the speakers, was away with it to the sea, and when this was done it must be far away into the sea, because if it was put into the sea, as at Brighton, some distance from the shore, the difference of specific gravity was so great between sewage and salt water that it rose to the top; and he had seen for $\frac{1}{2}$ mile or 1 mile in length the sewage floating at the top of the water—a nasty and a noxious thing. As a principle sewage works in towns must be carefully done. Typhoid fever had increased of late years, although typhus fever had gone down. Typhoid fever was eminently the disease of the water-closet system, and was manifestly the great test as to the perfection of sewage arrangements. Good and great as were the results of the work of the Registrar-General, they did not meet the occasion with which they had now to deal. It would be well that every town should post weekly the number of those diseases which came by sewage, and particularly typhoid fever. During the last twelve months Croydon alone had had more than one hundred cases of death from typhoid fever, and eleven hundred cases of typhoid fever; and when it was considered that of those cases each man had been ill upon an average ten weeks, and when this loss to the family and to the community was calculated, it would be seen that there was no cheaper thing to the entire community than that of keeping typhoid fever at a distance. Some people thought that by running rivers of water through sewage the difficulty was overcome; but mucus was untouched, indeed was not intended by nature to be acted upon by water. Contagious poisons, as far as could be determined, were conveyed by mucus, and hence it ought to be taken as a primary principle that those poisons must be destroyed at the earliest moment after they had passed into the sewage. He would not go into the extent by which the cost of this process might be reduced. It had been said, and this agreed with the result of his own inquiries, that it would cost at least 6*d.* per head of the population to precipitate the vicious matters in the sewage, but, whatever the cost, it ought to be done. Not only had known cases of disease to be dealt with; outbreaks of serious fever continually occurred; and he need hardly point to tho case that impended at this moment —the rise of the plague along the valley of the Euphrates. Were people prepared to meet this epidemic if it should reach this country, when some towns were spreading the excreta of their population over hundreds of acres of surface? He actually knew of a case in which sewage was being carried to acres of watercresses, simply that a town might obtain about £120 a year in order to reduce their expenses; and in that way the excreta might be spread over those watercresses and be distributed to the population of other cities. After the fæcal matter was precipitated the residuum must go into the earth, and then pass through a considerable amount of porous strata, where it might be ultimately destroyed. That it was so destroyed was shown by the deep springs of London, where the water, having filtered through the chalk, contained, as was found in the well at the Bank of England, the smallest possible trace of organic matter. Care must be taken that the residuum really went through the earth, and that the operation was carried out in such a way as not to create a nuisance. A town had no right to take its sewage into another district, and there, on the plea of the common good of humanity, cause such an amount of damage to others that it became a nuisanco. All chemical processes for obtaining manure from sewage should bo looked upon as subsidiary. As far as his experiments had gone, he found the manures that had been formed from sewage were almost useless. They did not produce effects equal to their theoretical equivalents. He had applied some kinds on beds in his experimental garden, crossing them diagonally, and crossing them in patches, but after he put in a valuable amount of the artificial manures made from sewage, he could not tell from the crops where they had been put on. Why they should be so impotent he could not tell, but their value could be tested by experience alone. If, as it ought to be, any benefit could be got, by making artificial manures, to lessen the cost of the proceedings, seek it; but, above all things, let nothing be done to sacrifice the public health.

Mr. Law said, having examined with some care the figures contained in the Appendix to Mr. Shelford's Paper, he was struck by an apparent anomaly in the estimated values of the precipitated phosphates, and had prepared the following tabulated statement to which he would direct attention:

—	Estimated value of Phosphate contained in Manure.	Estimated value of Phosphate derived from Sewage.	Estimated ultimate value of Phosphate added to Sewage.	Original actual Cost of same.	Increased value assumed to result from Manipulation.	
					Actual.	Per cent.
	A	B	C	D		
	£.	£.	£.	£.	£.	
Experiment No. 1 . .	225·61	41·45	184·16	120·71	63·45	52·6
" No. 2 . .	298·28	41·45	256·83	211·87	44·96	21·1
" No. 3 . .	385·57	41·45	344·12	212·71	131·41	61·8
" No. 4 . .	246·36	41·45	204·91	215·80	..	..
Mean	288·95	41·45	247·50	190·27	57·23	30·1

Column A showed the values, as estimated by Mr. Shelford at 3*s.* 3*d.* per unit, of the phosphates contained in the sewage. Column B showed the estimated values of the phosphate originally contained in, and derived from, the sewage itself. The average quantity of phosphoric acid contained in ordinary sewage had been variously estimated; by Dr. Hoffman at 1·85 grain per gallon, Dr. Letheby 1·74, Dr. Way 1·68, and by Dr. Voelcker at 1. It was stated in the Paper that the sewage experimented upon was a weak sewage, but, to be on the safe side, he had taken the highest valuation of 1·85 grain to the gallon, equivalent to 4 grains of tricalcic phosphate. This at 3*s.* 3*d.* per unit for 10,000,000 gallons gave £41·45, as shown in column B. Deducting 'B' from 'A' there remained the value shown in column C, viz., the estimated ultimate value of that portion of the phosphate originally added to the sewage as contained in the manure deposited; but if this was compared with column D, the actual cost of that same phosphate, as stated in the Paper, it appeared that the process of dissolving the phosphate in the sewage and depositing it had increased its value, in the first experiment 52 per cent., in the second 21 per cent., and in the third 62 per cent.; the mean of the four experiments being 30 per cent. It did not appear that this increased value arose from an increase in the quantity of the phosphate, but rather from the higher value per unit assigned to it. For instance, in the third experiment, 32 lbs. of phosphate were used, costing 1*s.* 5*d.*, whereas the phosphate obtained was barely 18 lbs. and was valued at 2*s.* 7*d.*, or an increase of more than three times its value by manipulation. Now considering that the phosphate contained in these manures was combined with from 66 to 80 per cent. of what had been significantly designated 'profligate associates,' he could not but think that the value of 3*s.* 3*d.* per unit did not express the true money value to the farmer of the phosphates contained in the manure derived from sewage, and that the mode of estimation adopted was likely to lead to fallacious results.

Mr. C. E. Austin observed that for the last ten years he had advocated a system of extracting the solid matter from the sewage at the earliest possible moment, collecting it in the branch drains, and not allowing it to go into the main sewer. This he had suggested might be accomplished by strainers changed and removed daily from the drains, and conveyed to a market garden, or some other place where the solid could be used as manure. This plan was adopted by a seaside colony commencing building, and, having been in work for the last nine years, had given satisfaction, and was now to be extended over the whole district within the jurisdiction of that Improvement Commission. He need not mention the difficulties of promoting a system of that sort, but having tried experiments with this system in two or three other places, no objections had been raised to the results. In one case, where it was tried for a year and a half in a town on the Thames, and where the analyses both of the sewage and the effluent waters were regularly published, although it gave perfect satisfaction, the local authorities finally abandoned it, and said, "If we adopt your system we shall have to pay for it, and afterwards we shall have to pay for the Government system," for a combined system of drainage was being held over them in terrorem. The process was a cheap one, costing only 2½*d.* per head for a population exceeding five thousand, and the solid matter could be used as manure. An acre of land would suffice, if required, to absorb the solid manure of a population of ten thousand for one year, and if that acre was planted with roses and strawberries, interlined with cabbages and celery, &c., the manure would be sufficient for four years; so that for a population of ten thousand only 4 or 5 acres would be needed to dispose of the solids. The admixture of silicate of soda with the fluid destroyed the mucus in a great measure, and by a second process of filtration at the outlet, or by a small surface irrigated, an effluent water equal in purity to the original Thames Conservancy standard was obtained. By extracting the solids at the earliest possible moment, the remaining contents of the sewers were more easily dealt with. The effluent water of the sewer, of which an analysis was shown, was purer than any sample of effluent water he had ever seen, showing that there was a great deal in extracting the solid matter before it was disintegrated. There was also the advantage that a greater fall could be given to the branch sewers, in consequence of a less fall being required for the main sewer, in which there would be scarcely any matter to form a deposit.

Mr. Abernethy, Vice-President, said, having for some years past paid attention to the question of the disposal of sewage, he had arrived at the conclusion that by the A B C system, the lime process, and other modes, an effluent water might be obtained of sufficient purity to be passed into rivers of ordinary volume. He was also convinced, from a certain amount of personal experience, that the solid residuum could be applied to agricultural purposes with benefit, but not that it could be at all regarded with a view to profit. Nor should town authorities regard it in that light; for if it cost 1*s.* per head per annum, it was to the interests of the population that the cost should be faced, and the sewage disposed of in the best possible manner. He felt strongly the necessity of preventing the pollution of rivers by sewage; and that even where sewage was passed into the sea, great care should be taken in the selection of the outlet, that it should be passed into the sea, at a part of the coast where the current would carry it into deep water. He had not yet had the pleasure of reading Sir John Hawkshaw's report on the disposal of the sewage of Glasgow; but if it was correctly described in a leading article in "The Standard" of the 3rd of April, 1876, he must congratulate Sir John Hawkshaw on the bold way in which he grappled with the subject, viz., by discharging the sewage of that city into deep water at Farland Head, far beyond the embouchure of the river Clyde.

On the 7th December last, he had stated at the Institution that the discharge of the sewage in the Thames at Crossness had had the effect of depositing a stratum of deep black mud over the original bed of the river, and that that stratum of fœtid mud was gradually extending up the river to Woolwich and beyond. That statement was met by Sir Joseph Bazalgette in these terms: "He was surprised to hear it stated that in consequence of the drainage of London, a large accumulation of mud had taken place in the river at the outfalls, and that there was a prospect of it impeding the navigation. He had never before heard such views expressed by any member of the Institution. He would ask whence the facts were gathered on which these conclusions were grounded. Since the metropolitan outfalls were first opened, he had had soundings taken in their neighbourhood, and he found that there was, at the present moment, less accumulation of mud than there had been before the outfalls were established."[1] Subsequently Sir Joseph had furnished a copy of his report, in answer to a letter from the Conservators of the Thames, dated 29th July, 1874, in which he stated: "By a comparison of the Board's soundings it appears that between the year 1867 and the present time, there has been a positive scour and improvement in the depth of this part of the river, to the extent of more than 300,000 cubic yards, or in other words, that part of the river is now 10 inches deeper than in 1867. This is the true test, and this figure represents practically the improvement which has taken place in the deepening of this part of the river since the opening of the Board's outfalls up to the present time. Although, doubtless, sewage is mixed with the mud deposits here and for several miles above and below London, the evidence above quoted goes to show that the sewage discharged into the river at Crossness tends to scour it rather than to form deposit."[2] That statement was so opposed to natural results and his own experience, that he sought further information from the officials of the Thames Conservancy Board, in order to account for the extraordinary phenomenon, that the sewage deposited at Crossness Point tended rather to scour the channel of the river than to form a deposit. He had been supplied with a list of the soundings, from which it appeared that the condition of things at the outlet of Crossness in 1861, previous to the discharge of the metropolitan drainage into the river was this—that immediately opposite Crossness, on the south side of the river, there existed a deep-water

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliii., p. 209.
[2] *Vide* Metropolitan Board of Works, Letter, &c., No. 718, July 1875.

channel, and also an extensive anchorage used by colliers, and termed the Colliers Section, No. 3. That anchorage no longer existed, nor did the deep navigable channel which then ran on the south side of the river, but in place of that a huge mud-bank had been formed of black deposit, undoubtedly from the sewage, so that the soundings were reduced from 22 feet to 10 feet, and from 22 feet to 11 feet, the difference extending far into the centre of the river. The survey made by the Conservancy Board last year showed most distinctly that the stratum of black mud was gradually extending up the river beyond Woolwich, and that the original clean gravel bed no longer existed. Sir Joseph Bazalgette had stated, in the discussion and in his reports, that at Crossness the general sectional area of the navigable channel had not diminished. That was accounted for in this way: most extensive dredging had been carried on on the northern side opposite Crossness by the Trinity Board to obtain ballast for shipping, so that the deep-water channel was now on that side of the river. That channel might be maintained as long as dredging was resorted to, but it would silt up when the dredging ceased, and it would cease when the gravel was impregnated with mud. He believed, therefore, it would be found necessary, probably at no distant period, to carry the sewage of the metropolis beyond the mouth of the Thames and to the sea into deep water, where it would no longer be a nuisance; for if matters remained as at present, the tidal flow, passing over a long continuous fœtid bed of mud, must pass up to the city of London in a contaminated state. As a proof of the contamination of the river, he was informed that while fish used formerly to be kept alive in the well-boats at Barking, they had subsequently been removed to Erith, then to Gravesend, and now they were obliged to be kept at the mouth of the river. He believed a large portion of the lighter sewage was carried by the flood tide high up the river. A bank of black deposit, visible at low water, had accumulated within a recent period in front of St. Thomas's Hospital, and being analysed by Dr. Letheby, was found to contain traces of sewage.

In discharging sewage into the sea, it was necessary that great care should be exercised in the selection of the outlet. At Margate, after a long discussion upon competing schemes, he was informed it had been resolved to discharge the sewage about 1½ mile eastward of the town into the sea, beyond a reef which projected at right angles to the shore, forming a low-water groyne. Eastward of that natural groyne there was another of the same character, and between them a sandy bay, so that the sewage discharged between those two natural groynes at low water, would be cooped up between them, and would remain permanently deposited at that point. Near high water, when the current was exceedingly strong, a portion would no doubt be carried back to Margate, and gentlemen enjoying the pleasures of natation might find articles parted with long ago in close proximity to their persons. Taking a broad view of the subject, the points to be considered were, the selection of proper outlets for the discharge of sewage, the best and most economical mode of utilising it for agricultural purposes, and of removing it from rivers, so that they might be no longer polluted, but restored to something like their original purity.

Sir JOSEPH BAZALGETTE said the Papers treated of two distinct modes of dealing with the excreta of towns, although they had been a good deal mixed up in the course of the debate. The first dealt with the appliances for receiving and removing fæcal matter from houses in a solid form, and taking it away in carts. The second proposed to extract the solid matter from the water, which had been made the carrier for its removal from towns. Dealing with the first Paper, he was struck by a statement that five-sixths of the whole of England was under what might be called the dry system. Even if a large proportion was subtracted for the rural districts, and attention was confined to towns, there would remain a number of places dealt with, according to this view, by the system of middens, pails, or devices of that kind. If that were so, it was important to have the best appliances for collecting and removing the deposit. For a long time much of the sewage must be so treated; but, in his opinion, that system was altogether unsuited to the present age. It was, if he might use the expression without giving offence, a barbarous system—a system by which the closet must be out of the house, the excreta must be exposed in the closet until covered from time to time with ashes, and men must come round to the house once a week with the cart to remove it to some place of deposit, where it must remain until it could be got rid of. It was not only a barbarous system, it was also a costly one. It was stated that at Birmingham the cost of the removal was 1*s.* per head per annum. That appeared to be a small amount, and very reasonable; but in London there was a population of four millions, and 1*s.* per head meant £200,000 a year, which capitalised at 5 per cent. was £4,000,000; that was equal to the cost of the Main Intercepting Sewerage of London, and such an expenditure would therefore double the Intercepting Sewerage in order to perpetuate a barbarous system. If such a system were introduced at Bournemouth, Torquay, Brighton, or any similar town, the place would be ruined. The only really proper system fitted for this country was the removal of all sewage by water. The water came quietly and silently into the houses and carried away everything decomposing and that was of a disagreeable character, and it was no longer present to the senses, and there was no annoyance by meeting people in the streets taking it away. Some people would say, "Oh, there is the difficulty of the ventilation of sewers; typhoid fever, and all sorts of evils, arise from the water system;" but the best practical answer to that was the sanitary state of London. Though it had the largest population that had ever been congregated together in the United Kingdom, there was no other town of the same class more healthy, and the air of which was more pure. The smell in the streets of continental towns which had not the water system would be found much more disagreeable than in London, and the death rate was higher. He therefore contended that the water system was the only civilised and proper way of getting rid of the sewage of large towns. The outfall could be placed wherever it was desired. General Scott, who had devoted a great deal of time and talent to the consideration of the subject, and had worked hard at a mode of extracting solid sewage from liquid, had stated that the conclusion he had arrived at was that an outfall into the sea, or some other place where the sewage would for ever be disposed of, would be the best method that could be adopted. In previous debates he had heard highflown ideas about the value of sewage, and the profit to be made out of it, but it seemed now to be admitted that it could not be dealt with with a view to profit, and expenditure must be incurred.

It had, again, been stated by Mr. Abernethy, that the discharge of the metropolitan sewage at the outfalls had had the effect of filling up the bed of the Thames. Even if correct, this would form no real argument for a change in the plan of dealing with the sewage involving a large expenditure. All that would be necessary in that case would be a little extra dredging; but Sir Joseph Bazalgette thought that objection had been answered on the last occasion when it was raised. In the year after the opening of the outfall sewer at Barking Creek and Crossness, in 1867, there was a decrease of 480,000 cubic yards in a length of $\frac{3}{4}$ mile of river opposite the Crossness Outfall at Halfway Reach. The following year there was an increase of 142,000 yards; the next year a decrease of 216,000 yards; then an increase of 277,000 yards, and in the following year 279,000 yards; again a decrease of 260,000 yards, and the next year 53,000 yards, making a total decrease of 311,000 cubic yards between 1867 and 1874. That showed that, if anything, there was a scour at the outfall, but there were some more important influences at work, such as those due to the rainfall and the general scour of the river, rather than the amount of sewage poured into the river. Some of these causes might be found in the continuous washing away of the alluvial banks by the tidal waters, or might be due to the discharge into the river of silt from the docks and from other sources, or to improved land drainage into the upper reaches of the Thames, or soil brought down from the uplands by heavy rains, or to the effect of piers or other works in the river. The positions of shoals so formed might be expected to shift, as indeed they did, in accordance with the variation in the strength and set of the current, arising from change in the direction and force of the wind and quantity of upland and tidal water. An inquiry was held some years ago, and it was determined that if there was an increase of deposit at the outfall, the Thames Conservators should be entitled to call upon the Metropolitan Board to dredge so much as was added to the bed of the river; but the Thames Conservators, from that date to the present, had never exercised that power. If it were not a little beside the question, he could show also that it was not only the fact, but the logical result, that sewage could not deposit in the bed of the river.

With reference to dealing with sewage at outfalls, where a clear outfall could not be obtained, but where the sewage had to be dealt with first, then some one or other of the processes which had been laid before the Institution might be adopted. Those processes, however, had not been so satisfactory as could be desired. One gentleman advocated the lime process of precipitating solids from sewage at the outfall. This was perhaps one of the oldest methods, having been in operation more than twenty-five years. It was quoted in the Paper as being in operation at Birmingham, and in the outskirts of that town there were large precipitating reservoirs, into which milk of lime was poured, and the sewage deposited from the effluent water. That deposit was removed from time to time by the best class of machinery that could be designed, and was thrown upon several acres of land which were covered with sewage sludge. That sludge was allowed to dry, and, when sufficiently dry, was dug into the land, and crops raised upon it. Such an operation might be tolerated in the outskirts of a manufacturing town, but it would be highly objectionable and most detrimental if applied to watering-places. At Birmingham the Corporation had tried to get a sewage farm on which to deposit the sewage from the tanks and irrigate the land; but they had failed, and within the last twelve months an action had been brought against them by Sir Charles Adderley for polluting the waters of the river Tame and flooding his land, and they had to pay him a large amount of compensation. The fact was the effluent water could not be sufficiently purified, especially in times of flood. Again, with regard to Leicester, where the system had been in operation many years, he was being consulted with a view to establish a sewage farm there. He visited Leicester a few months ago, shortly after heavy rains, and he found the machinery had stopped. On asking the reason, he was told that it was on account of the heavy rains. There was so much water coming down that it could not be dealt with, and it was allowed to go into the river and over the lands flooded by it. This was the great difficulty with all these different processes. One gentleman, who advocated the A B C process, had spoken of his experiments at Crossness. He said that he had for three months been trying how far the sewage could be purified, and that if he had only had three months more he could have shown how it could be made to pay. What were the facts of the case? That gentleman had from the 1st of January, 1870, to the 30th of November, 1872, and during that time he only dealt with $\frac{1}{700}$th part of the sewage of the metropolis. If he was not satisfied, as the result, that the process could only be worked at a great cost, and could not be made to pay, certainly those persons who were impartially looking on were; and another two years, or a much longer period, would probably not have satisfied him that it could not be made to pay. He did not propose to speak of the various modes of dealing with sewage by precipitation. Most of them could be used under certain conditions, and there were circumstances where they must be had recourse to; but it could only be done at great cost, and, after all, was only a palliative and not a cure. He believed that the purification of sewage by irrigation was the most satisfactory mode of disposal, but still it could only be done at a loss, and was a method to be resorted to only when no better could be found. He concluded by expressing his conviction that the sanitary question—the removal of the sewage of towns in an inoffensive and healthy manner—was the first thing to be considered, and that it could be best done by water carriage. The problem of the disposal of sewage was not yet solved, and until it was solved the best thing to do was to get rid of it by an outfall which would carry it far away. The members were greatly indebted to the gentlemen who had discussed the question so earnestly, and had given so much time to its consideration, for that was the way in which things were eventually brought to perfection. In the meantime their first duty was to study the sanitary question, and leave the matter of profit to be settled hereafter.

Vice-Admiral Sir FREDERICK NICOLSON said he could in every respect confirm the facts stated by Mr. Abernethy. There could be no question that if a large quantity of sewage was poured into a river, there must be a deposit somewhere. The latest surveys in the neighbourhood of Crossness showed that a shoal was undoubtedly being formed precisely opposite the outfall. No doubt Sir Joseph Bazalgette's figures were correct from his point of view; but they resulted, as Mr. Abernethy had stated, from considerable dredging having been carried on on the opposite side of the river. Sir Joseph had alluded to the fact that he had not yet heard from the Conservators of the Thames that they required that part of the river to be dredged. The Conservators had for the last few years been carefully watching this part of the river; they had taken careful soundings, and had had the deposits analysed: and he felt confident that it would not be long before it would be necessary to have a large amount of dredging done, not only close to Crossness, but in the reach above. He believed when that time arrived, both the Board of Works and the Conservators would jointly do all in their power to keep the river as pure as they could, and, above all, to keep the navigation always open.

Mr. LEMON thought the injudicious advocates of sewage utilisation had done more to retard the solution of the sewage problem than the strongest opponents. The same system had been recommended in every place regardless of local circumstances, and the result had been a considerable financial loss. He agreed with General Scott that the best thing to be done with sewage was to throw it away: that it was no longer to be looked upon as something to make money out of, but must be got rid of as quickly as possible. After seeing every process in the kingdom for dealing with sewage, he had arrived at the same conclusion as Sir Joseph Bazalgette, viz., that the dry-carriage system was a barbarous one, and, moreover, it was costly; for where the dry-closet system had been carried out there was also a system of sewers to carry off the slops. Having had to lay out a scheme for draining a large district, where there were some strong advocates of the dry system, he took the trouble to make a few calculations as to what would be the saving in the area of the sewers required if the dry system were adopted, and he found that the same area of sewers was requisite for the dry system as for the water-closet system. Both systems were in vogue at Birmingham; but in that town, according to the Reports of the Sewage Inquiry Committee, no less than £250,000 had been laid out for the drainage. Again at Manchester, where the dry system had almost entirely been adopted, the cost of the sewage works had been £340,000. This would not be so much complained of if the dry system were a good one, but nearly all the large towns adopting it had had injunctions against them for polluting the rivers. He therefore considered that the advocates of the dry system had not solved the sewage problem. The value of the manure had been put at 2*s.* 6*d.* per head. As far as his experience went that was a theoretical value, and never had been and never would be realised. It was a value which no farmer could afford to give for dry sewage, because, being in such a large bulk, the cost of cartage and labour was proportionally greater, and it was to his interest to buy a high class and more concentrated manure. Being anxious to try this question at one time, he gave some of these low-class manures to a scientific farmer, who told him he did not care about having more, and that for such manures he certainly could not give more than 2*s.* or 3*s.* a ton. That manure was valued by theoretical chemists at 30*s.* a ton. The great difficulty in the precipitating process was the disposal of the sludge. Drying it was sure to be more or less a nuisance, and the system adopted at Birmingham appeared to be the less objectionable of the two. One fatal objection to the precipitating system was that the ammonia was lost, and it was that alone which gave the product any value.

Mr. Milburn explained the dry-sewage system, as carried out by the new Town Manure Company at Bilston, which proved that two of the conclusions arrived at in Mr. Redgrave's Paper were correct: first, that it was possible to effect the collection of excreta without creating a nuisance; and, secondly, that it was possible to procure from excreta collected on the dry system a concentrated manure which would repay the cost of collection. The Town Manure Company was originally started at West Bromwich, but the system not succeeding there, application was made to his firm to erect the machinery for treating and drying night-soil. At that time the Company had not taken adequate steps to overcome the difficulty of preventing a nuisance arising from the noxious vapours, and the town authorities therefore gave them notice to go. Previously to this, however, the commissioners of Bilston had inspected the system, and had had thoroughly explained how the nuisance could be avoided, and had come to terms with the Company to start operations. The machinery was erected for drying the excreta, and the Milburn Company's process for consuming the noxious vapours was also applied. For nearly a year the manufacture had now been continuously carried on, without creating the slightest nuisance, while the Government inspector had reported favourably upon it, and on the condition of the town under the Company's management. The population of Bilston was about twenty-five thousand, and the number of privies more than two thousand. The company were now clearing the whole of the night-soil of the town; and when all the privies were supplied with the new tubs, there would be as nearly as possible 130 tons of raw night-soil produced at Bilston weekly, yielding from 13 to 14 tons of finished manure, containing, according to an analysis by Dr. Voelcker, nearly 8 per cent. of ammonia, and 5 per cent. of phosphate of lime. This was a valuable manure, far more so than had hitherto been obtained from excreta. The total cost of collection and production was as nearly as possible £55 a week, and for that they could obtain 13 to 14 tons of manure, worth £7 10*s.* to £8 a ton. He therefore thought the Town Manure Company had so far solved the question, that they had demonstrated to a certainty that a concentrated manure could be produced from night-soil without causing the slightest nuisance, and that the manufacture would yield a large margin over and above the cost of production. The drying machinery had since been considerably improved, so that 1 lb. of coal would evaporate about 7½ lbs. moisture, or nearly 50 per cent. more than it did previously.

Mr. MONSON said the primary consideration with regard to the disposal of sewage was the health and convenience of the community at large; and in this light the water-closet system had great advantages over all others, the removal from the premises being effected by the mere pulling of a handle or the turning of a tap. The waste water from houses and manufactories was generally sufficient for transport, and the nuisance occasioned by conveying the excreta through the streets was abolished. The best, and indeed the only, method of really purifying sewage was first to remove the solids, and then to pass the liquid through aërated porous soil, upon the intermittent principle, the land being properly drained. Stiff clay soil was unsuited for the purpose, and sewage applied to such land left the land scarcely better than if it had only been filtered. Pail-closets were opposed to sanitary principles, and to every feeling of delicacy and refinement. They depended for their efficacy upon the night-soil man, whose visits were always inconvenient and unpleasant; and the pail being used by several persons, was disgusting: and its contents gave off noxious odours which were injurious to health and an annoyance to the inhabitants of the house. The cost of this system, too, was great. First, there was the cost of horses, carts, and pails; then the annual outlay for repairs, team and manual labour, and, finally, the expense of manufacture and disposal. On the other hand, the water-carriage system was cheap and efficient. The death-rate of London, with its water-carriage system, was 26 per 1000, whilst that of Manchester, with its pail system, was 34 per 1000.

Mr. Russell Aitken remarked, through the Secretary, that he had been for some years Engineer for the city of Bombay, where, as usual in Indian cities, the night-soil was collected by hand. When he went to Bombay in 1866, from one part of the city containing 500,000 inhabitants, the amount of night-soil taken away did not exceed forty carts, or about 30 tons. Afterwards, by an improved system of collection, and the use of the new style of air-tight night-soil carts, the amount removed from the same district was increased to 120 tons, or to more than four times what it was formerly. The cost of collecting the whole of the night-soil of a population of more than 700,000 persons was, for the year 1867, about £60,000 per annum, being at the rate of about £1 per ton of night-soil. When the night-soil had been collected it was flushed out to sea, and floated down the harbour at high water. In 1867 he proposed to substitute the water-carriage system for the removal of night-soil, instead of the present inefficient mode of collecting, or rather attempting to collect it, by hand every morning. He was earnestly pressed to adopt various projects for the so-called utilisation of sewage, such as irrigation, &c. He, however, adhered to his plan for throwing it into the sea at that part of the island which was most remote from the densely inhabited parts of the town, and where the sewage would be swept by the ebb-tide well out into the Indian Ocean. From his experience of the water-closet system when applied to warm climates, he was of opinion that it was much more healthy as well as cleaner than the system of removal of night-soil by hand. With regard to the pail system, adopted by some towns in England apparently with success, when compared with the water-closet system, he had no doubt but that if the water-closet system were used in separate little houses, as was absolutely necessary when the pail system was adopted, it would be found that the water-carriage system was much the healthier mode for removing night-soil. It was the abuse of the water-closet system which had led to the disastrous outbreak of fever for which the use of this system was made responsible; and if a regulation were passed that every water-closet should be provided with a large ventilator or window, communicating directly with the outer air, little or nothing would be heard of the injurious effect of sewer gas, whilst the health of the community would be materially improved.

Mr. EACHUS stated, through the Secretary, that the Authors of the Papers appeared rather to have over-estimated the returns obtainable under the dry and precipitation systems. Mr. Redgrave stated that the annual cost of the removal of ashes and excreta was 1*s.* per head of the population, and he estimated the value of the pail stuff at 2*s.* 6*d.* per head. Mr. Shelford put the cost and assumed value of the manure produced by Whitthread's process at £3 3*s.* and £3 18*s.* 6*d.* per ton respectively. Both these estimates showed a profit of from £1,200 to £1,500 a year in the case of a town of 20,000 inhabitants—a result not obtained in practice. Mr. Eachus found the results of the last six months' trial at Edmonton to be that both irrigation and a precipitation process—that known as Hille's—had cost the local board in each case about the same, namely, £6 per million gallons treated, or 1*s.* 2*d.* per head per annum, inclusive of interest on capital expended, for the two systems. The farm was let to a yearly tenant, and up to the present time had only been partly prepared; in the comparison of the two systems it had been assumed that the whole amount necessary for the completion of the farm had been expended in addition to the actual expenses. With these facts before him, and bearing in mind the difficulty of disposing of the manure or sludge in the case of the dry and precipitation processes, he was of opinion that irrigation, or, as it was sometimes paraphrased, intermittent downward filtration, was the system best adapted for sewage utilisation, especially as, although taking the cost as being the same for the two systems, the productive power of the land was increased much more, and the country thereby became indirectly a gainer. Of course no system could be universally adopted, as if the whole of the sewage of the country were utilised by irrigation there would be from $\frac{1}{8}$ per cent. to 1 per cent. of the whole country under sewage. Hence the advantage of dealing with some of the large centres of population in the manner in which London had been, and Glasgow was recommended to be, dealt with. Chemical processes were most useful in combination with irrigation, or where that system could not be adopted and the standard of purification required was not a high one.

Dr. J. H. GILBERT observed, through the Secretary, that there could be no doubt whatever that the interception or dry processes referred to by Mr. Redgrave were an immense improvement upon the old midden-pit or common privy systems; but no such plan could be accepted as a solution of the sewage difficulty. About four-fifths, or more, of the manurial value of human excretal matters were due to the urine. It was a desideratum with all such systems to exclude as much of the urine as possible, and the complete separation of the liquid from the solid dejections had been recommended. Of course, this would much reduce the value of any dry manure so produced, which was already so low as not to be worth more than its carriage beyond the immediate locality. Without such special separation, at the outside about one-third of the urine would be collected with the fæces. Under any such dry system there was, therefore, from two-thirds to the whole of the urine, besides all wash and other house drainage, still to be dealt with; and if the liquid had to go into a stream which served as the water supply for other populations, sooner or later purification would be enforced. Passing the liquid through land was not only the best mode of purification, but promised the greatest return for the constituents it contained—whether profit to the towns, depended on many local circumstances. Then as to precipitation methods. There could be no doubt that any one of those referred to by Mr. Shelford would be a vast improvement upon doing nothing whatever with sewage that had to be turned into an open stream. No such plan was, however, likely to collect more, and would generally collect less, than one-fourth of the nitrogen of the sewage in the solid manure. This one-fourth was, moreover, the least active and least valuable part. These plans also, as a rule, carried down the phosphates, but in a precipitated, not in a soluble, form; and in more than one scheme soluble phosphate had been used, and was converted from this more valuable into the less valuable precipitated condition. The estimates of the value of the nitrogen reckoned as ammonia in such a manure, containing only from 1 to 2 per cent. of it, at the same rate as was provided in guano containing about 12 per cent., and in a much more soluble condition, was entirely fallacious; as also was the valuation of precipitated phosphate at 3*s*. 3*d*. per unit. Would, then, such precipitated manures pay for their manufacture as such? He thought not. If the process were adopted mainly as a means of purification, what was the result? About three-fourths of the nitrogen of the sewage would remain in the liquid. This would exist, in the main, not as nitrates, but as ammonia and soluble organic compounds. This liquid, with all other house drainage, remained to be dealt with. He did not think that such a liquid would eventually be allowed to run into a water-supply stream. Passing it through the land would best purify it, and would yield the largest return. If the sewage were employed for irrigation, the less taken out of it, beyond the sludge, before use, the better; and if the phosphates were removed, they should be returned either to the sewage or to the land irrigated. In fact, where irrigation was to be eventually adopted the less effective the precipitation process the better; indeed, the exclusion of the natural sludge was all that was desirable. He was by no means unconscious of the many difficulties involved in the general adoption of sewage irrigation, but he believed if rivers were to be kept from pollution, it would eventually have to be adopted, wherever practicable, before the liquid was discharged into them.

Mr. Gilbert Redgrave, in replying upon the discussion, said he wished, in the first instance, to repudiate the idea, which seemed to have suggested itself to several of the speakers, that he appeared as the advocate of an interception system as opposed to a water-carriage system. He had carefully guarded himself against this in the Paper. Finding how large a portion of the population was dependent upon some interception system, he had endeavoured to show that the subject was worthy of the careful consideration of the engineer. It was too much the rule at the present time to lay down a hard-and-fast law that, from an engineering point of view, there was nothing at all worth thinking of but some system of water-carriage, and to assert that water and nothing else but water had been designed by nature to remove human ordure. It needed neither the advocacy of Sir Joseph Bazalgette nor of Mr. Monson to persuade them, for doubtless every one was prepared to admit, that the water-closet was the most decent, the most comfortable, and the most perfect contrivance for the removal of human excreta from habitations. But, notwithstanding that the dry-collection system had been denounced as "barbarous" and "incomplete," it must be remembered that it was sufficient for all the requirements of by far the largest portion of the inhabitants of this country, and that it was used with cleanliness and comfort even in the houses of the wealthy, while the water-closet was the comparatively modern luxury of the few. But beyond all these considerations of mere comfort, he had endeavoured to show that the persons occupying the "uncivilised quarters" of towns were not easily persuaded to use mechanical contrivances of any kind; and for them, he knew by experience, any form of water-closet was quite out of the question. In nine cases out of ten the trap became stopped up with filth, and the first remedial measure adopted by the "lady of the house" was to put the kitchen poker through the bottom of the pan, which doubtless had the effect of unstopping it for good and all. The best arrangement for such a neighbourhood was a shallow midden of small dimensions, or some form of pail, with quick and therefore frequent removal of the contents. It was useless to talk about "invading the privacy of the house," among a population possessing but one privy to every four houses, and thinking themselves well off to get that. Why, such people only complained about overcrowding when the separate families, living in each room, sought to take in lodgers! People who made objections of the above kind had never studied the question *in situ.* The Author's only attempt had been to bring under the notice of the meeting what had been done by the officers of the Local Government Board, and to show what was being effected for bettering the "conditions of life" in large manufacturing towns. Dr. Voelcker had cast doubts upon the possibility of making any profit out of the excreta collected on the dry system, grounding his opinion upon the experience gained in Holland and Belgium from the sale of fæcal matters in their natural condition. He had, however, admitted that it might be possible to extract salts of ammonia from urine, as a paying process. Now Mr. Redgrave had shown that the profit he had spoken of was to be derived by extracting the fertilising elements from the liquids and presenting them to the farmers in a concentrated form. He was glad to learn from Mr. Milburn that actual working on a large scale at Bilston had confirmed his views concerning the profits to be derived from dealing with dry sewage. Mr. Alderman Taylor had found fault with the statement that the Rochdale system was founded upon the process of M. Goux. Mr. Netten Radcliffe's report was his authority, but he was glad to accept the alderman's correction in the matter. While a great admirer of the Rochdale system, he could not agree with the present plan of manufacturing manures there, for the process of absorbing the urine with ashes degraded its value too much. While on this question, he might remind Mr. Smee that he was opposed in principle both to the ash and to the earth-closet system as now practised. He objected strongly to the admixture of the liquids and the solids in the receptacle, and considered that if deodorants were employed, they should be used, in small quantities, to the solids alone, and be of such a nature as not to diminish the value of the fæces as fertilisers. Rochdale deserved all praise, he thought, for having led the van in the way of improved midden construction, and improved methods of collecting and treating dry-sewage. When referring in his general conclusions to "improved" midden construction, his remarks were intended to apply to some form of pail- or tub-system, and not to some alteration of the old-fashioned fixed receptacle. Mr. Fowler had found fault with the great expense of the tub-closets at Leeds. He thoroughly agreed that if the cost of collecting the night-soil amounted to 12*s*. 3*d*. per ton, it was high time that the authorities there should learn what was being done elsewhere; in many other towns the cost was less than half the figures quoted. Mr. Fowler complained that no mention had been made of the systems in use at Salford; true he had omitted to speak of Mr. Fowler's invention, which might, he considered, be useful, but which, however, was not a dry-closet, and could not be included among dry-systems. In estimating the value of the excreta collected upon the dry system he had, from actual observation, ascertained the proportion of the liquids and the solids retained in the tubs, and the proportion otherwise voided. He found that under similar conditions these quantities varied within very narrow limits. In some towns a small proportion of what might be considered as the chamber-slops found its way into the tubs, but 1 lb. of mixed pail-sewage, collected per head per diem, was near the truth. The value of this sewage, if it could be obtained as a concentrated manure, was undoubtedly about 16*s*. per ton, or 2*s*. 6*d*. per head per annum. But it must not be assumed, because he had found the pail-sewage to represent this value, that this sum could be realised in practice as a net profit. From this total must first be deducted the cost of collection of the pail-stuff, namely, as he had shown, 1*s*. Then the drying, manufacture, acid, and labour in preparing the concentrated manure would not fall far short of 1*s*. 3*d*. per head, leaving only a small margin of profit when all the expenses had been met. He was convinced that towns which undertook the collection of pail-sewage must not look for much in the shape of returns from the manufacture and sale of manures beyond their actual working expenses.

Mr. Shelford, in reply, expressed surprise at the remarks of Mr. Rawson, as so far from attacking the A B C process, he had shown that at Leamington it was cheaper than any other to which he had referred. He had stated that the Native Guano Company "had the settlement of the sewage question at Leamington in its hands if it sold the manure at £3 10*s*. per ton:" and again, "that the Company had actually made a market at Leamington at that price." There could be no doubt that the failure of the Crossness experiment was due to the cost of the chemicals only, for if the other expenses had been *nil*, the dry manure would still have cost £4 7*s*. 6*d*. per ton. Moreover, the sum paid for chemicals by the Native Guano Company would have made the cost of the dry manure £3 12*s.* 6*d.* per ton before any labour was spent upon it. The invoices proved this, while the Company affected to sell manure at a profit of £3 10*s.* per ton. He was glad to learn that the Company was now practising at Leeds on a different principle; and if it was manufacturing a dry manure for 20*s.* per ton, as stated by Mr. Rawson, which was only two-thirds of the estimated minimum cost in the Paper, it was doing more than had yet been effected elsewhere. But unfortunately Mr. Rawson had not given that figure upon his own authority, though he had been for years acquainted with all the details of the A B C process; and Mr. Alderman Tatham's statement certainly required corroboration before it could be received as a fact. He ought perhaps to explain, in reference to the reflections made upon him personally, that he had not used any privileged information, but that all the statements in the Paper were based on documents open to the public, or for which publicity had been sought.

The opinion entertained by Dr. Voelcker, as to the costliness of disposing of sewage matters, founded upon experience in Belgium and Prussia, failed to show how far the cost there was due to land carriage, and to the amount of moisture in the sewage matters. This affected the cost materially, and no fair comparison could be made without reducing each manure to its value when dry. He had made some experiments to determine the quantity of moisture in sewage sludge, and he found that, when solid enough to shovel, it contained 80 per cent. of moisture, but was quite liquid when it contained 85 per cent. or more. Any sewage matter containing 90 per cent. of moisture would yield only 10 per cent. of dry manure, which, at the high estimate of 150*s.* per ton, would make the matter containing it worth only 15*s.* per ton. The solid sewage matter would yield only 20 per cent. of dry manure, and therefore would not be worth more than 30*s.* per ton. But if from these amounts the minimum cost of collection were deducted, given by Mr. Fowler as 12*s.* 3*d.* per ton at Leeds, and a similar amount were deducted for cost of distribution, sale, &c., there would be a loss on the liquid matter, and a possible profit of 5*s.* 6*d.* per ton on the solid matter. Hence the amount of moisture was an important element in the question. It had been stated by Mr. Melliss that the cost of treating the sewage of Coventry was 1*s.* 7*d.* per head per annum, which, if it referred to the conversion of all the sewage into a dry manure, would be nearly the minimum cost given in the Paper; but he believed that a great part of the sludge at Coventry was not dried. If all the sludge were dried the cost would be more than 1*s.* 7*d.* per head; but the process was nevertheless a cheap one, on account of the small quantity and low price of the chemicals, and the excellent arrangement of the works. He was not responsible for the information given in the Appendix to his Paper, which had been so severely criticised, and had been defended by Mr. Meyerstein, who had supplied it, and who had stated his authority for adopting such high values.

In conclusion, he would endeavour to sum up the scope and purpose of his Paper, which had been slightly misapprehended by some speakers. His object had been to describe the present position of precipitation as a practical means of settling the sewage question, and he thought that such a description would be incomplete without an account of the work done by the Native Guano Company, in the first place, at Leamington, with a small quantity of chemicals, and afterwards at other places with larger quantities, until at Crossness the cost and quantity of the chemicals employed brought about an exemplary failure. Speaking generally, he thought that precipitation processes might be classed under two heads—cheap precipitation, and recuperative precipitation.

Cheap precipitation included the lime process, the A B C process as now practised at Leeds, Dr. Anderson's process, and others; and in favour of this class the most that could be said was that the necessary loss in working might eventually be reduced to a minimum of 6¼*d.* per head per annum. In precipitation everything depended upon the value obtainable for the manure, and in this lay all the difficulty at the present time, partly because of the difference among chemists upon it, and partly because of the popular prejudice against sewage manures. Mr. Redgrave had stated that concentrated manures were sold at prices approximating to their theoretical value, while feeble manures rarely fetched more than from one-fourth to one-tenth of that value. This seemed to be admitted in the discussion; and he had been informed, by persons acquainted with the trade, that a manure which sold for less than £4 per ton was practicably unmarketable. If that were so, cheap precipitation could only be carried on at a loss, and however useful it might be as a palliative, it could never become a permanent solution of the sewage question.

Recuperative precipitation included the Phosphate Sewage, and the processes of Mr. Dugald Campbell and Mr. Whitthread, the two last of which had been referred to in detail in the Paper as the most recent examples of the class, and not as processes which he advocated. To them the value of the manures produced was vital, but it seemed as yet impossible to obtain the facts from chemists, for on one side the precipitated phosphates had been valued at 2*s*. 3*d*. per unit, and on the other side the higher price of 3*s*. 3*d*. per unit.

Whatever the values of the constituents of a manure, they became more important in proportion as the manure was either fortified or concentrated, and until they were settled, both by chemists and agriculturists, there could be no permanent solution of the sewage problem by precipitation, even where precipitation was applicable. Meanwhile there was a dead lock, and progress was impossible unless the town authorities made up their minds to pay part of the cost. For this purpose he had given sufficient information to enable them to determine what sum they could safely pay, and had suggested £2 2*s*. 10*d*. per million gallons of sewage. He thought that, small as that sum was, it would suffice to stimulate the latent energy of private enterprise, leading to the removal of the difficulty in many places adapted to precipitation, and eventually, he hoped, to a permanent solution of the sewage question. But in this country it was customary to go by steps, and the next step was that the towns must pay.

April 4 and 11, 1876.

GEORGE ROBERT STEPHENSON, President, in the Chair.

The discussion upon the Papers, No. 1,474, on "Sewage Interception Systems, or Dry-Sewage Processes," by Mr. Gilbert Richard Redgrave, and No. 1,475, "The Treatment of Sewage by Precipitation," by Mr. William Shelford, occupied the whole of both these evenings.

The following Candidates were balloted for and duly elected on the 4th of April:—James Ramsay, as a Member; Charles Sneath Allott, Rodolfo de Arteaga, Stud. Inst. C.E., Henry Stracey Barron, Charles James Bowstead, Alfred Davidson, Thomas Wilberforce Davies, Daniel Earnshaw, Norman Garrard, Charles Currie Gregory, Francis Augustus Heath, Thomas Jefferies, John Mackenzie, John O'Connell, Benjamin Langford Forster Potts, Colonel John Davenport Shakespear, Oswald Turner, Robert Edward Wilson, and Thomas Percival Wilson, as Associates.

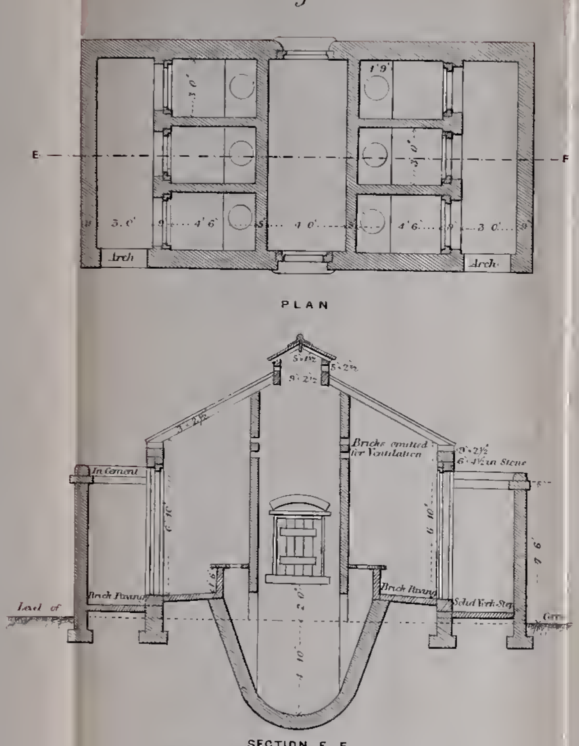
It was announced that the Council, acting under the provisions of Sect. III., Cl. 8, of the Bye-Laws, had transferred Richard Hammersley Heenan, Leonard Robert Roberts, and Christopher Thwaites from the class of Associate to that of Member.

Also that, under the provisions of Sect. IV. of the Bye-Laws, the following Candidates, having been duly recommended, had been admitted as Students of the Institution:—Roderick Walter Baynes, William Alfred Benson, Robert Charles Brebner, Charles James Grierson, George Richard Gwyn, John Blackley Little, Thomas Joseph Myles, Sydney Prestije, Edward Quick, Henry John Saunders, Charles Henry Shortt, James Robert Tickell, Carleton Fowel Tufnell, and Walter Clifford Tyndale.

On the 11th of April it was resolved to adjourn for a fortnight, in order to avoid holding a meeting on the evening of Easter Tuesday, April the 18th.

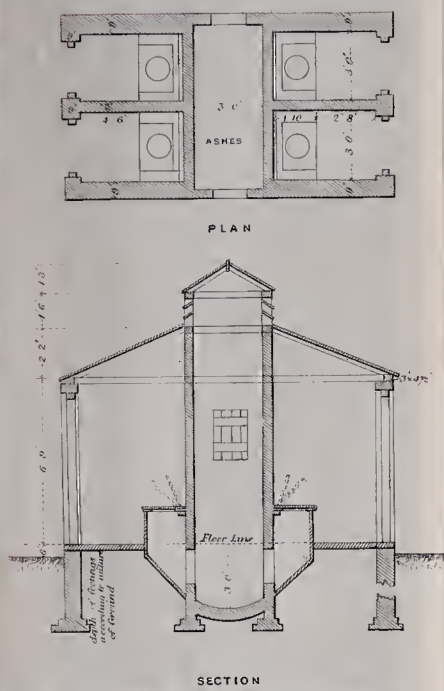
LONDON: PRINTED BY WILLIAM CLOWES AND SONS, STAMFORD STREET, AND CHARING CROSS.

Fig. 1.



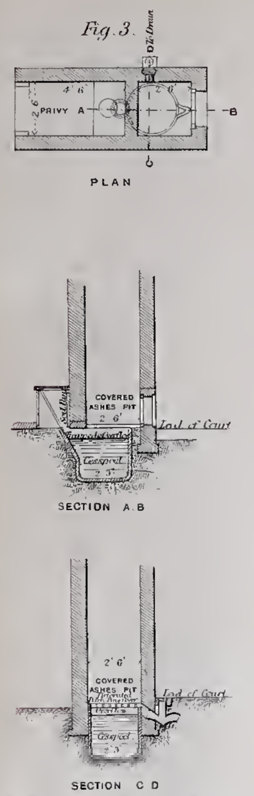
MIDDEN CLOSET USED AT NOTTINGHAM.

Fig. 2.



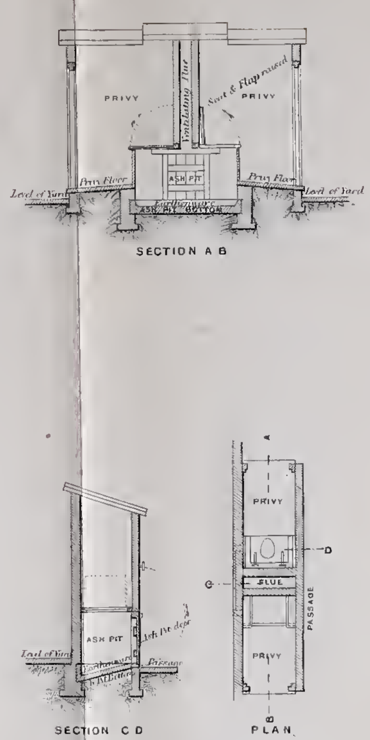
MIDDEN CLOSET USED AT STAMFORD.

Fig. 3.



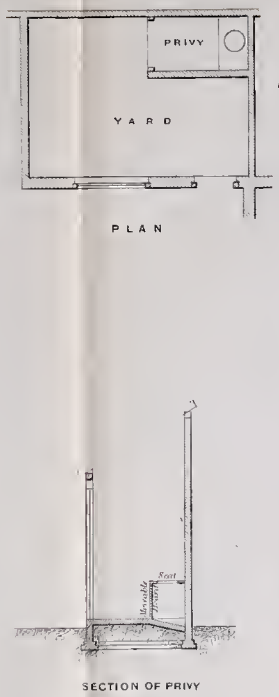
MIDDEN CLOSET USED AT BURNLEY.

Fig. 4.



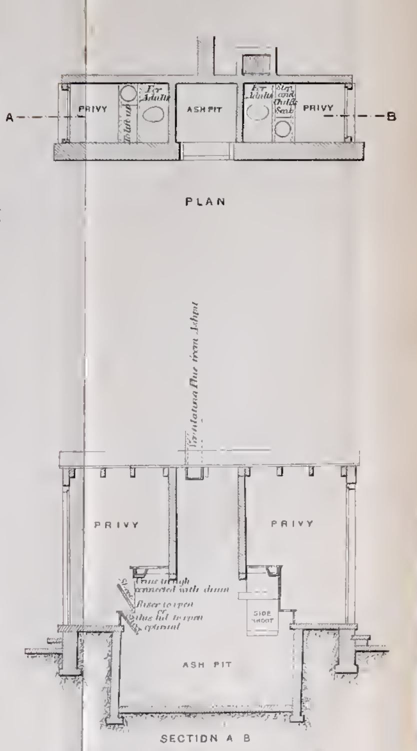
MIDDEN CLOSET USED AT MANCHESTER.

Fig. 5.



MIDDEN CLOSET USED AT HULL.

Fig. 6.

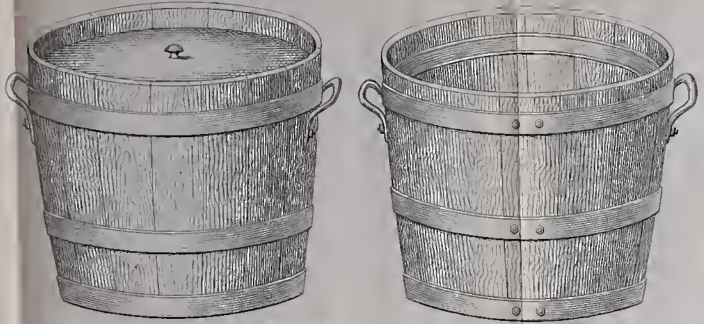


MIDDEN CLOSET USED AT STOCKPORT.

Scale, ⅜ of an Inch : 1 Foot

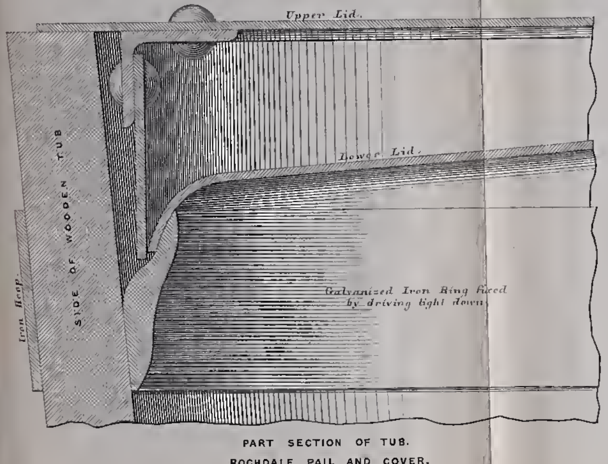
GILBERT R. REDGRAVE DEL.

Fig: 8.



EXCREMENT PAIL WITH LID ON FULL, TO RETURN TO WORKS.

EXCREMENT PAIL EMPTY, READY FOR USE.

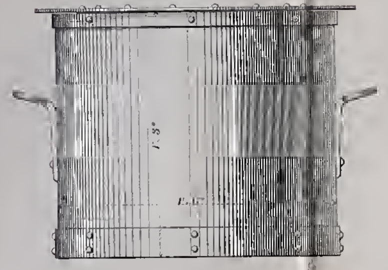


PART SECTION OF TUB.

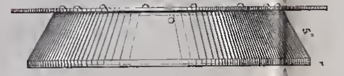
ROCHDALE PAIL AND COVER.

Full Size.

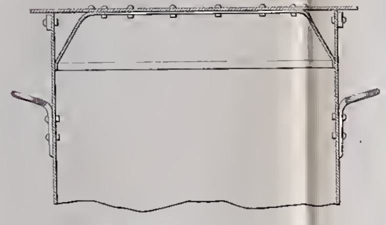
Fig: 9.



PAIL.



LID.

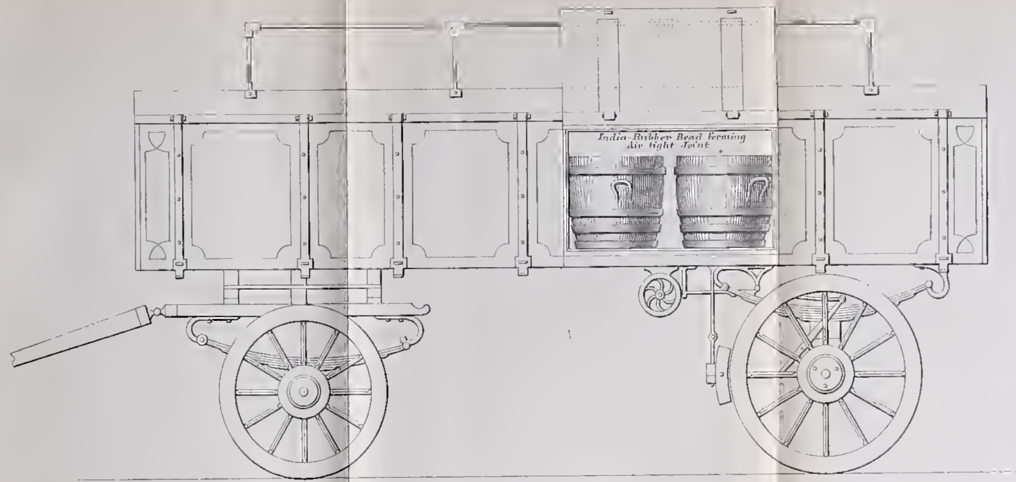


SECTION SHEWING THE LID IN POSITION.

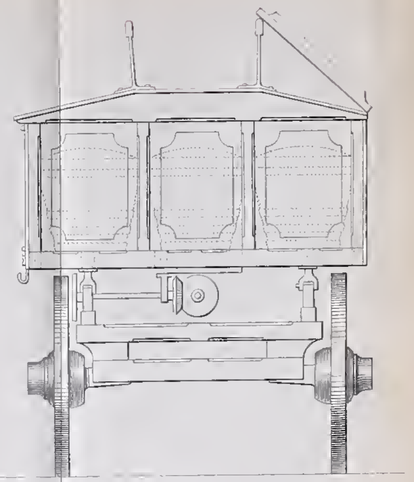
BIRMINGHAM PAIL AND COVER.

Scale 1½ Inch = 1 Foot

Fig: 10.



SIDE ELEVATION OF NIGHT SOIL VAN.

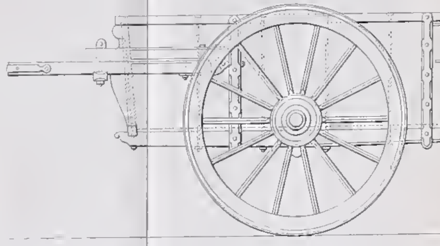


END ELEVATION OF NIGHT SOIL VAN.

ROCHDALE NIGHT SOIL VAN.

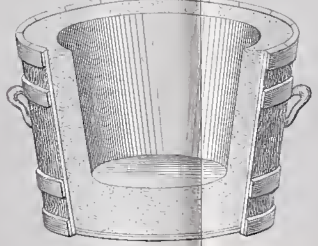
Scale: 2 Feet = 1 Inch.

Fig: 11.



ASH CART.

Fig: 7.



ABSORBENT RECEPTACLE.

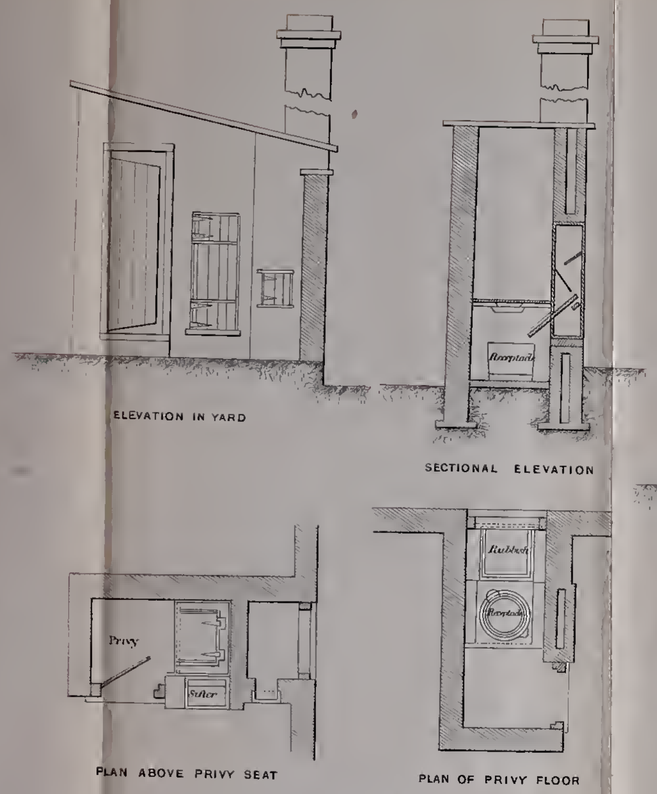
MOULD.

LINED PAIL USED FOR "GOUX" SYSTEM.

GILBERT R. REDGRAVE, DEL.

THOS. KELL & SON, LITH. KING ST. COVENT GARDEN

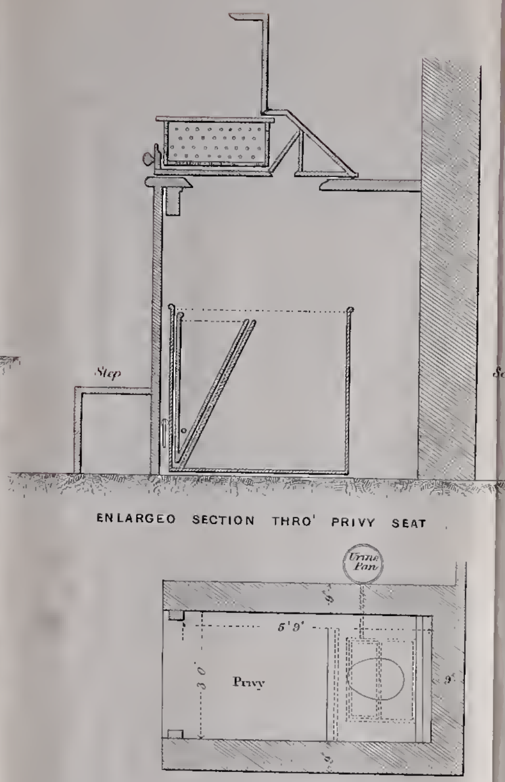
Fig. 12



Scale, 4 Feet to an Inch.

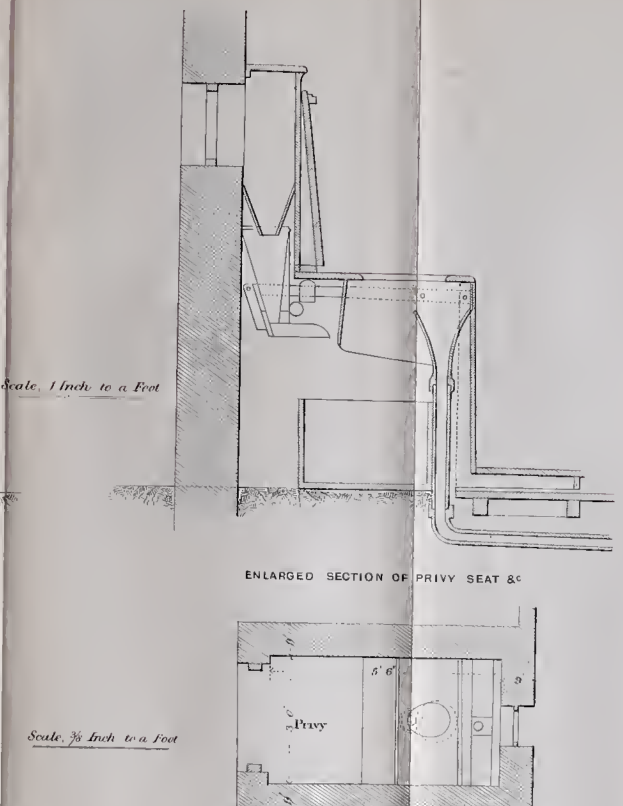
MANCHESTER ASH CLOSET.

Fig. 13.



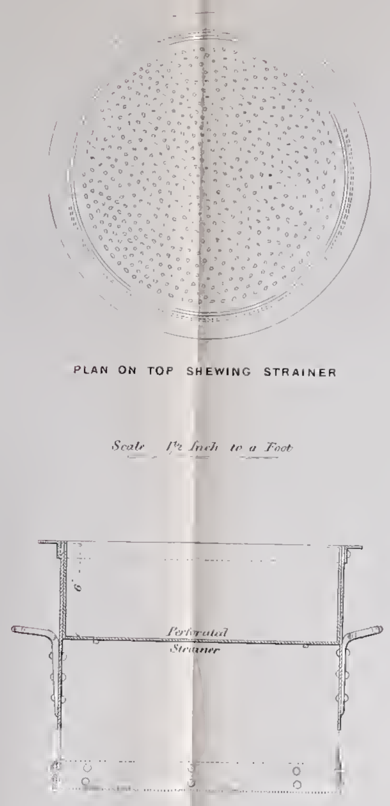
OR BOND'S DRY CLOSET.

Fig. 14.



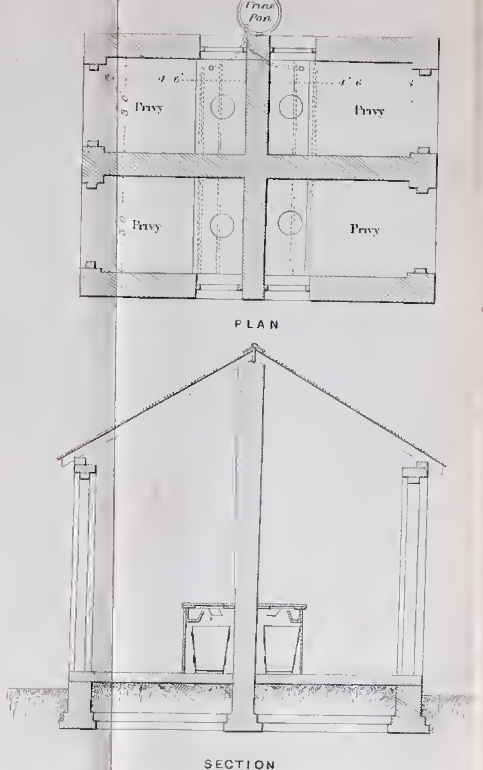
GIBSON'S DRY CLOSET.

Fig. 15.



SEPARATOR PAIL USED BY CARBON FERTILIZER COMPY

Fig. 16



Scale, 4 Feet to an Inch

PAIL SYSTEM WITH SEPARATE URINE COLLECTION

THE TREATMENT OF SEWAGE BY PRECIPITATION

PLATE 6.

CROSS SECTION OF SEWER

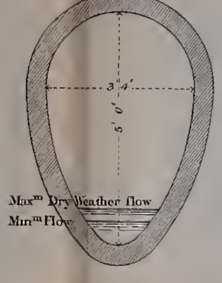
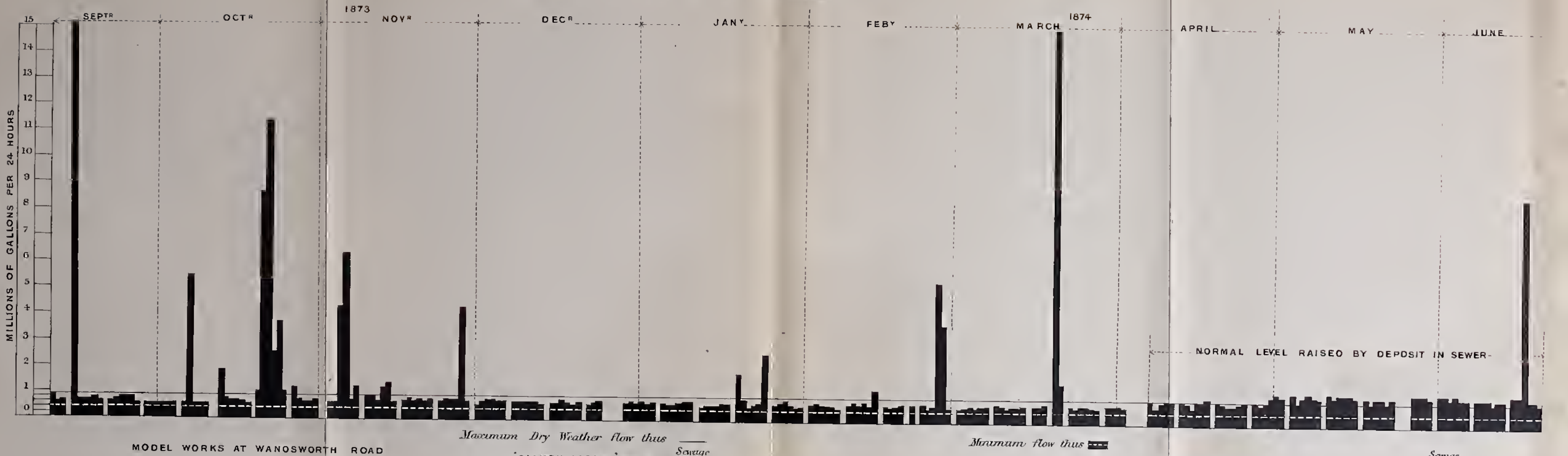
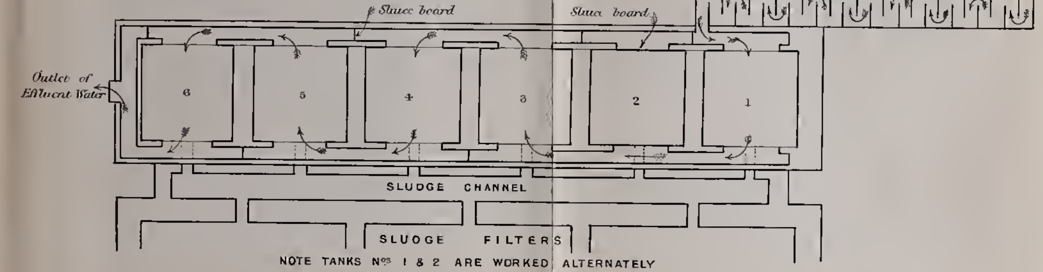


DIAGRAM OF MAXIMUM DAILY FLOW OF SEWER.



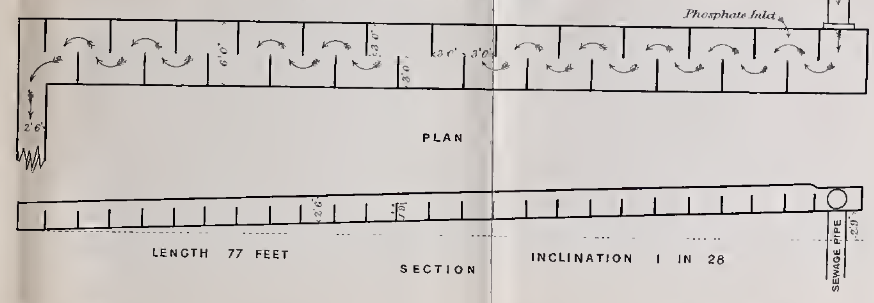
MODEL WORKS AT WANDSWORTH ROAD

PLAN OF PRECIPITATION TANKS.



NOTE TANKS N^os 1 & 2 ARE WORKED ALTERNATELY

"SALMON LADDER" MIXER AT TOTTENHAM



LENGTH 77 FEET

SECTION

INCLINATION 1 IN 28

W. SHELFORD DEL^T

THO^S KELL, LITH 40 KING S^T COVENT GARDEN